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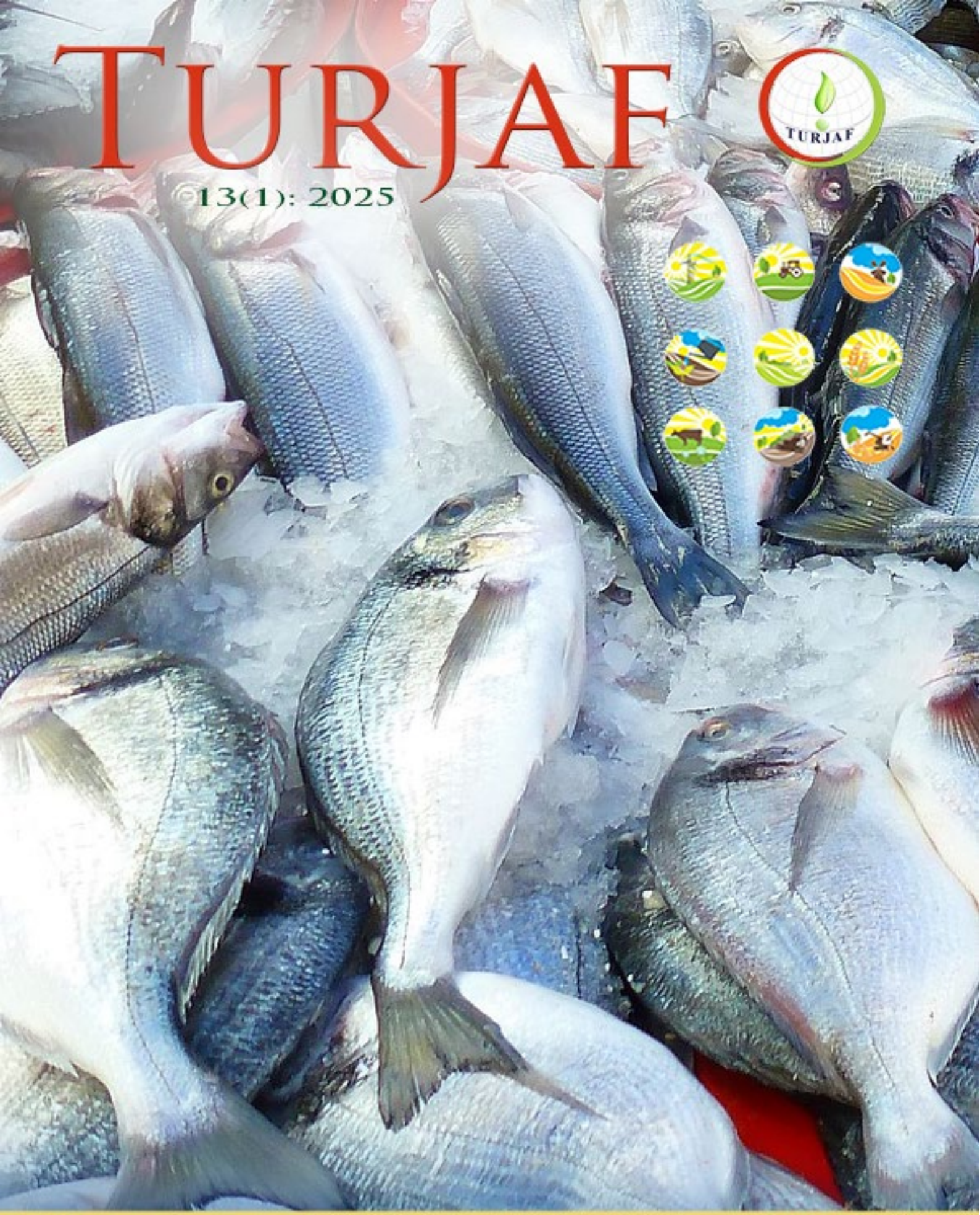

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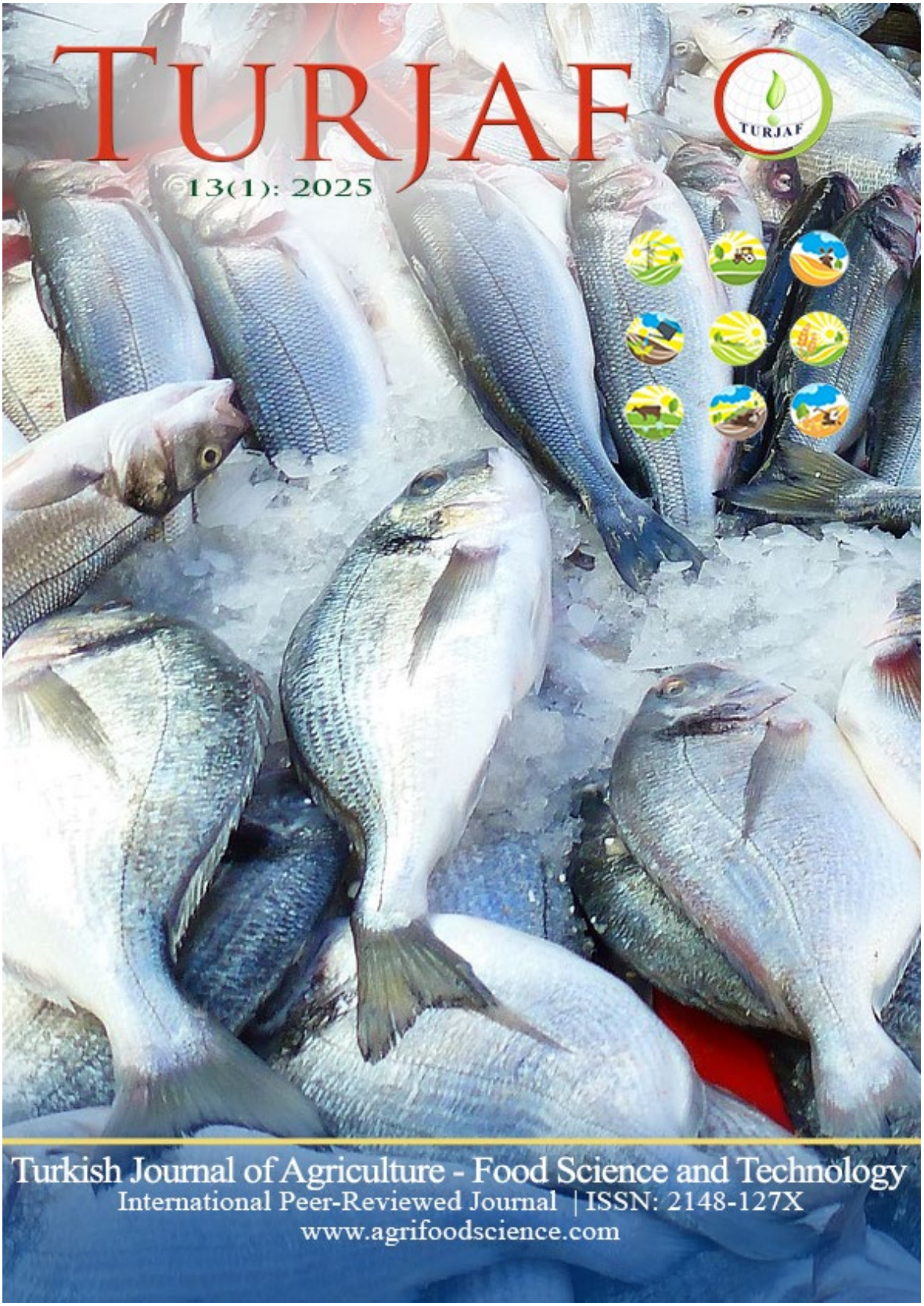

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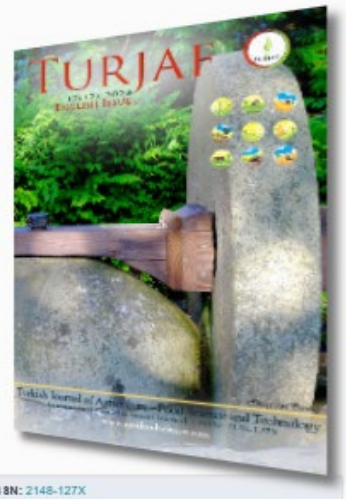

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Determination of Agricultural Mechanization Level; Kırşehir-Çiçekdağı Case

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ABSTRACT

Agricultural mechanization includes the design, production, development, marketing, publication and training, operation and use of all energy sources, mechanical tools and equipment used to develop agricultural areas, to carry out all kinds of agricultural production and to process the products (Zeren et al., 1995). Determining the level of agricultural mechanization using agricultural mechanization indicators is of importance in revealing the agricultural mechanization levels of regions and countries. In this study, the agricultural mechanization characteristics of Çiçekdağı district of Kırşehir province were examined. In the study, the data of Turkish Statistical Institute (TUIK) for the years 2023 and 2024 and the data obtained from Çiçekdağı District Agriculture Directorate were used as material. In this context, the number of agricultural tools and machinery (number of tractors, number of combine harvesters, number of first and second class soil tillage tools and machines, number of sowing-planting and maintenance machines, number of plant protection machines and number of harvesting-threshing machines) of Çiçekdağı district were also included in the study. Mechanization level; The number of tractors, combines and agricultural implements was determined and the indicators of the level of agricultural mechanization were determined as tractor/1000 ha, ha/tractor, kW/ ha and average tractor power (kW). According to the data, the number of tractors increased from 35.97 to 38.74 per 1000 ha, while the land area per tractor decreased from 27.79 ha to 25.81 ha. While the power per tractor increased from 2.49 kW/ha to 2.68 kW/ha, the average tractor power remained constant at 69 kW.

Türk Tarım – Gıda Bilim ve Teknoloji Dergisi, 13(1): 1-5, 2025

Tarımsal Mekanizasyon Düzeyinin Belirlenmesi; Kırşehir-Çiçekdağı Örneği

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Çiçekdağı

ÖZ

Tarımsal mekanizasyon, tarım alanlarını geliştirmek, her türlü tarımsal üretimi yapmak ve ürünlerin işlenmesini de gerçekleştirmek amacıyla kullanılan tüm enerji kaynağı, mekanik araç ve gerecin tasarımı, yapımı, geliştirilmesi, pazarlanması, yayım ve eğitimi, işletilmesi ve kullanılması konularını içermektedir (Zeren ve ark., 1995). Tarımsal mekanizasyon göstergeleri kullanılarak tarımsal mekanizasyon düzeyinin belirlenmesi, yörelerin ve ülkelerin tarımsal mekanizasyon seviyelerinin ortaya konmasında önem arz etmektedir. Bu çalışmada Kırşehir ili Çiçekdağı ilçesinin tarımsal mekanizasyon özellikleri incelenmiştir. Çalışmada, Türkiye İstatistik Kurumu'nun (TUİK) 2023 ve 2024 yıllarına ait verileri ile Çiçekdağı İlçe Tarım Müdürlüğü'nden elde edilen veriler materyal olarak kullanılmıştır. Bu kapsamda Çiçekdağı ilçesinin tarım alet ve makine sayıları (traktör sayısı, biçerdöver sayısı, birinci ve ikinci sınıf toprak işleme alet ve makine sayısı, ekim-dikim ve bakım makinesi sayısı, bitki koruma makinesi sayısı ve hasat-harman makinesi sayısı) da çalışmaya dahil edilmiştir. Mekanizasyon düzeyi; traktör, biçerdöver, tarım aletleri sayısı tespit edilmiş olup ve tarımsal mekanizasyon düzeyi göstergeleri; traktör/1000 ha, ha/traktör, kW/ ha ve ortalama traktör gücü (kW) olarak belirlenmiştir.Verilere göre, traktör sayısı 1000 hektar başına 35,97'den 38,74'e yükselmiş olup , traktör başına düşen arazi alanı ise 27,79 hektardan 25,81 hektara gerilemiştir. Traktör başına düşen güç 2,49 kW/ha'dan 2,68 kW/ha'ya artarken, ortalama traktör gücü 69 kW seviyesinde sabit kalmıştır.

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Giriş

Tarımsal mekanizasyon hem bitkisel hem de hayvansal üretim faaliyetlerini geliştirmek için güç kaynaklarının ve makinelerin kullanımını kapsar. Bu bağlamda, güç kaynaklarının ve tarım araçlarının tasarımı, üretimi, geliştirilmesi, işletilmesi, pazarlanması, yayınlanması, eğitimi ve kullanımı gibi çeşitli faktörler giderek daha önemli hale gelmektedir. Bu unsurlar, tarımda ileri üretim tekniklerinin uygulanması için olmazsa olmazdır.

İşletme faaliyetlerini rekabetçi bir seviyede tutmak için, mekanizasyon uygulamalarının her üretim sezonunun sonunda bir tarımsal işletmenin genel verimliliği üzerindeki etkisini değerlendirmek çok önemlidir. Bu değerlendirmenin temel amacı, aynı bölgede ve farklı ülkelerde benzer üretim sektörlerindeki işletmeler arasında mekanizasyon uygulamalarının yoğunluğunu ve verimliliğini karşılaştırmaktır. Uygulama derecesi ve işletme karlılığıyla ilgili verimlilikteki farklılıklar, yöneticiler için hayati öneme sahip hususlardır. Sonuç olarak, mekanizasyon seviyesini değerlendirmek için küresel olarak tanınan göstergeler vardır (Zeren, 1991).

Traktör, tarımsal mekanizasyonda en yaygın kullanılan güç kaynağıdır. Sonuç olarak, bir bölgedeki tarımsal mekanizasyon seviyesini değerlendirmek için temel kriterlerden biri, ekili birim alan başına traktör gücüdür (kW/ha). Bu ölçüm, mekanizasyon seviyelerinin en doğru göstergesi olarak kabul edilir. Ayrıca, 1.000 hektar başına traktör, traktör başına hektar, traktör başına ekipman ve traktör başına ekipman ağırlığı gibi diğer değerler de mekanizasyon seviyesini değerlendirmek için kullanılır (Işık, Güler, & Ayhan, 2003; Koçak, 2006; Sabancı & Akıncı, 1994).

Tarımsal mekanizasyon, tarım alanlarının geliştirilmesi, her türlü tarımsal üretimin yapılması ve ürünlerin işlenmesinde kullanılan tüm enerji kaynaklarının, mekanik alet ve ekipmanların tasarımı, üretimi, geliştirilmesi, pazarlanması, yayım ve eğitimi, işletilmesi ve kullanımını kapsamaktadır (Zeren ve ark., 1995). Tarımsal mekanizasyon göstergeleri kullanılarak tarımsal mekanizasyon düzeyinin belirlenmesi, bölgelerin ve ülkelerin tarımsal mekanizasyon düzeylerinin ortaya konulması açısından önemlidir.Bu amaç çerçevesinde yapılan çalışmada Kırşehir ili Çiçekdağı ilçesindeki tarımsal mekanizasyonun özellikleri incelenmiştir. Araştırmada 2023 ve 2024 yıllarına ait Türkiye İstatistik Kurumu (TÜİK) verileri ile Tarım İlçe Müdürlüğü'nden alınan veriler kullanılmıştır. Çiçekdağı ilçesinde bulunan traktör sayısı, biçerdöver sayısı, birinci ve ikinci sınıf toprak işleme ekipmanları, ekim ve dikim makineleri, bitki koruma makineleri ve hasat-harman ekipmanları dahil olmak üzere çeşitli tarım alet ve makinelerinin analizi yapılmıştır. Mekanizasyon düzeyi, makine sayısının belirlenmesi ve tarımsal mekanizasyon göstergelerinin hesaplanması yoluyla değerlendirilmiştir.

Materyal ve Yöntem

Materyal

Çiçekdağı İlçesinin Genel Özellikleri

Çiçekdağı, Kırşehir ilinde 39° ila 37° kuzey enlemleri ile 34° ila 24° doğu boylamları arasında yer almaktadır. 950 km²'lik alanı kaplayan ilçede 13.842 hektar orman bulunmaktadır ve 1.220 metre yükseklikte yer almaktadır. Toplam nüfusu 18.038'dir, 6.604'ü merkezdedir, 2 belediye ve 44 köyü vardır. İl merkezine 66 km uzaklıktadır (Anonim, 2023a).

İlçenin doğu kesiminde Paleozoik seri, granit, siyenit ve diyorit gibi magmatik kayaçlarla karakterizedir. İlçenin önemli bir kısmı, özellikle Çiçekdağı Deresi yataklarında belirgin olan Tersiyer formasyonlarından oluşur ve burada geniş alanlar Neojen ve Oligo-Miyosen serileriyle kaplıdır. Bu bölgelerde ayrıca Kuaterner seriler de tespit edilmiştir. Ayrıca ilçenin kuzey kesiminde Oligo-Miyosen dönemine ait jipsli seriler yaygındır. İklim karasaldır, yaz sıcaklıkları tropikal hava kütlelerinin etkisiyle artarken, kış sıcaklıkları kutup hava kütlelerinin varlığı nedeniyle önemli ölçüde düşer. Kırkkindi'deki ortalama yıllık yağış 340 mm olarak kaydedilir ve en yüksek yağış seviyeleri Nisan ayında, en düşük yağış seviyeleri ise Ağustos ayında görülür. İlkbahar aylarında, öncelikle yükselen sıcak hava kütlelerine atfedilen önemli bir konvektif yağış görülür. Buna karşılık, cephesel yağış, bölgedeki mevsimsel iklim değişikliklerini yansıtan kış aylarındaki baskın yağış biçimidir (Anonim, 2023a).

Araştırmada Kullanılan Verilerin Sağlanması

Çalışmada, Türkiye İstatistik Kurumu'nun (TÜİK) 2022 ve 2023 yıllarına ait verileri ile Kırşehir ili Çiçekdağı ilçesi Tarım İlçe Müdürlüğü'nden elde edilen veriler kullanılmıştır. Veriler, Çiçekdağı ilçesine özgü traktör, biçerdöver, birinci ve ikinci sınıf toprak işleme alet ve makineleri, ekim ve dikim ekipmanları, bakım makineleri, bitki koruma ekipmanları ile hasat ve harman makineleri sayılarını içermektedir.

Yöntem

Kırşehir ili Çiçekdağı ilçesinin tarımsal mekanizasyon özellikleri incelenmiştir. Çalışmada materyal olarak Türkiye İstatistik Kurumunun (TUİK) 2023 ve 2024 yıllarına ait verileri ve Tarım İlçe Müdürlüğünden alınan veriler kullanılmış olup tablolar verilmiş olup değerlendirme yapılmıştır.

Çiçekdağı İlçesinin; traktör sayısı, biçerdöver sayısı, tarım alet-makine sayısı ve tarımsal mekanizasyon seviye göstergeleri hesaplanmış olup mekanizasyon seviyesi belirlenmiştir.

Bulgular ve Tartışma

Tarımsal mekanizasyon derecesi hakkında bilgi veren en önemli göstergeler traktör sayısı, tarım alet-makineleri ve mekanizasyon seviyesi göstergeleridir. Tablo 1'de, Türkiye İstatistik Kurumu verilerine göre; Kırşehir ili Çiçekdağı ilçesindeki biçerdöver sayısı son 2022-2023 yıllarında yaş gruplarına göre verilmiştir (Anonim, 2023b).

Tablo 1'de yeni (0-5 yaş, 6-10 yaş) biçerdöver sayısında artış olduğu görülmektedir. 0-5 yaş biçerdöver sayısı 69'dan 75'e, 6-10 yaş biçerdöver sayısı ise 38'den 42'ye çıkmıştır. Ancak 11-20 yaş arası biçerdöver sayısı 21'den 18'e, 21 yaş ve üzeri biçerdöver sayısı ise 3'ten 1'e düşmüştür. Bu veriler incelendiğinde Çiçekdağı ilçesinde biçerdöver sayısının arttığı ve yenilendiği görülmektedir (Anonim, 2023b).

Tablo 2'de 2022 yılında toplam traktör sayısı 1293, 2023 yılında ise yaklaşık %8 artışla 1395 olarak verilmiştir. Tablo 2 incelendiğinde Çiçekdağı ilçesinde genellikle iki çeki demirli traktörler kullanılmaktadır.

Traktörler güçlerine göre sınıflandırılmaktadır. 2022'den 2023'e kadar her güç aralığındaki traktörlerde artış olmuştur. Bunun nedeni tarımsal mekanizasyonun en önemli güç kaynaklarından biri olmasıdır. En yüksek artış iki dingilli (51-70 hp) traktörlerde görülmüştür (Anonim, 2023b).

Birçok makine türünde artış gözlemlenmiştir. Bu, tarımda mekanizasyonun ve teknolojik gelişmelerin benimsenmesinin arttığını göstermektedir. Kültivatör: 2022'de 6282, 2023'te 6429, yani 147 adetlik bir artış görülmüştür. Kültivatörler, toprak işleme ve yabancı otlarla mücadelede kullanılan makineler olup, daha verimli ve hızlı bir şekilde toprağı işlemek için önemlidir. Bu artış, tarımda daha fazla mekanizasyonun tercih edildiğini ve iş gücünün azalmasıyla birlikte verimlilik artışının sağlandığını gösterir (Sabancı, A., & Akıncı, İ.1994). 2022'de 6332, 2023'te 6426, yani 94 adetlik bir artış görülmüştür. Kimyevi gübrelerin düzgün bir şekilde dağıtılması, ürünlerin sağlıklı büyümesi için kritik öneme sahiptir. Bu makinelerin kullanımındaki artış, verimlilik ve ürün kalitesini artırmaya yönelik bir eğilimi gösteriyor. Ayrıca, bu artış, tarımda gübreleme uygulamalarının daha hassas ve etkin bir şekilde yapıldığını yansıtmaktadır.

Tablo 1. Biçerdöver sayısı (yaşa göre)
Table 1. Number of combine harvesters (by age)

Biçerdöver(yaş)	2022	2023
0-5	69	75
6-10	38	42
11-20	21	18
21 ve üzeri	3	1

*(Anonim, 2023b); (Anonymous, 2023b)

Tablo 2. Çiçekdağı ilçesinin traktör sayısı
Table 2. Number of tractors in Çiçekdağı district

Güçlerine Göre Traktörler	2022	2023
25-34 BG	30	33
35-50 BG	117	124
51-70 BG	645	669
70 BG'den Fazla	501	519

(Anonim, 2023b), (Anonymous, 2023b)

Tablo 3. Kırşehir- Çiçekdağı İlçesi Tarım Alet ve Makinalarının Sayıları
Table 3. Number of Agricultural Equipment and Machinery in Kırşehir- Çiçekdağı District

Makine İsmi	2022	2023	Makine İsmi	2022	2023
Ark Açma Pulluğu	252	261	Kepçe (Tarımda Kullanılan)	309	326
Dişli Tırmık	1630	1644	Kuluçka Makinesi	11	11
Diskli Traktör Pulluğu	701	641	Kuyruk Milinden Hareketli Pülverizatör	4184	4215
Diskli Tırmık (Diskarolar)	2783	2796	Meyve Hasat Makineleri	1	1
Diskli Anız Pulluğu (Vanvey)	575	591	Mısır Silajı Makinesi	75	81
Hayvan Pulluğu	7	6	Motorlu Pülverizatör	384	392
Kültivatör	6282	6429	Motorlu Testere	-	1188
Kulaklı Traktör Pulluğu	7863	8067	Motorlu Tırpan	78	91
Kulaklı Anız Pulluğu	133	137	Pnömatik Ekim Makinesi	453	488
Kombikürüm (Karma Tırmık)	179	210	Rototiller	83	90
Merdane	344	352	Saman Aktarma-Boşaltma Makinesi	54	57
Ot Tırmığı	250	263	Santrifüj Pompa	638	647
Toprak Frezesi (Rotovatör)	100	122	Sap Döver Ve Harman Makinesi (Batöz)	80	76
Balya Makinesi	235	264	Sap Parçalama Makinesi	17	16
Biçer Bağlar Makinası	12	13	Sap Toplamalı Saman Yapma Makinesi	118	124
Çiftlik Gübresi Dağıtma Makinası	63	84	Sedyeli, Motorlu Pülverizatör Tozlayıcı Kombine Atomizör	59	58
Kimyevi Gübre Dağıtma Makinası	6332	6426	Sırt Pülverizatörü	1730	1913
Kombine Hububat Ekim Makinası	7229	7302	Silaj Makinesi	59	59
Kombine Pancar Hasat Makinası	31	31	Su Tankeri (Tarımda Kullanılan)	2166	2241
Orak Makinası	34	38	Süt Sağım Makinesi (Elle)	1175	1225
Pancar Hasat Makinası	163	168	Süt Sağım Tesisi	15	15
Patates Dikim Makinası	12	13	Tarım Arabası	8392	8559
Patates Sökme Makinası	13	14	Taş Toplama Makinesi	21	19
Tınaz Makinası	100	98	Termik Motor Pompa	469	449
Traktörle Çekilen Hububat Ekim Makinası	1120	1142	Toprak Burgusu	66	69
Anıza Ekim Makinesi	10	8	Toprak Tesviye Makinesi	51	52
Atomizör(İlaçlma makinesi)	47	49	Tozlayıcı(İlaçlama makinesi)	14	13
Çayır Biçme Makinesi	160	167	Üniversal Ekim Makinesi (Mekanik) (Pancar Mibzeri Dahil)	67	71
Damla Sulama Tesisi	266	330	Ürün Kurutma Makinesi	2	1
Derin Kuyu Pompa(Sulama makinesi)	298	315	Ürün Sınıflandırma Makinesi (Selektör Hariç)	1	1
Dip Kazan (Subsoiler)	214	219	Yağmurlama Sistemi	2377	2569
Elektrikli Porma	783	740	Yayık	90	89
Fide Dikim Makinesi	3	3	Yem Dağıtıcı Römork	63	71
Hayvanla ve Traktörle Çekilen Ara Çapa Makinesi	191	194	Yem Hazırlama Makinesi	299	327

(Anonim, 2023b), (Anonymous, 2023b)

Tablo 4. Çiçekdağı İlçesinin Tarımsal Mekanizasyon Düzeyinin Hesaplanan Göstergeleri
Table 4. Calculated Indicators of Agricultural Mechanization Level of Çiçekdağı District

Yıllar	Mekanizasyon Düzeyi Hesaplanan Göstergeleri			
	Traktör/1000 ha	ha/Traktör	kW/ha	Ortalama Traktör Gücü (kW)
2022	35,97	27,79	2,49	69
2023	38,74	25,81	2,68	69

Diskli Tırmık (Diskarolar) 2022'de 2783, 2023'te 2796, yani 13 adetlik bir artış gözlemlenmiştir. Diskli tırmıklar, toprak hazırlığı sırasında toprağı karıştıran ve hava almasını sağlayan önemli aletlerdir. Bu makinelerdeki artış, toprağın daha verimli bir şekilde işlenmesi ve tarımsal üretimin iyileştirilmesi amacıyla kullanılan makinelerin sayısının arttığını gösterir. Kombine Hububat Ekim Makinası: 2022'de 7229, 2023'te 7302, yani 73 adetlik bir artış yaşanmıştır. Hububat ekimi, modern tarım makineleriyle daha hızlı ve verimli yapılabilmektedir. Bu makinelerdeki artış, ekim süreçlerinin daha verimli hale geldiğini ve çiftçilerin iş gücünü en iyi şekilde kullanmaya çalıştıklarını göstermektedir. Balya Makinesi: 2022'de 235, 2023'te 264, yani 29 adetlik bir artış yaşanmıştır. Balya makineleri, ot, saman ve diğer tarımsal atıkların toplanmasında ve işlenmesinde kritik öneme sahiptir. Bu makinelerdeki artış, özellikle hayvancılıkla uğraşan çiftçilerin, saman ve ot üretimini verimli bir şekilde yapmalarını sağladığını göstermektedir. Bazı makinelerde ise düşüşler gözlemlenmiştir. Bu azalmalar, teknolojik geçişler veya tarımsal üretim süreçlerindeki değişikliklere işaret etmektedir. Diskli Traktör Pulluğu: 2022'de 701, 2023'te 641, yani 60 adetlik bir azalma olmuştur. Diskli pulluklar, toprak işleme işlemlerinde kullanılan önemli araçlardır. Azalma, alternatif toprak işleme makinelerinin (örneğin, kültivatörler veya diskli tırmıklar) kullanımının artmasına bağlı olabilir. Ayrıca, çiftçilerin daha verimli toprak işleme yöntemlerine yönelmesi de bu azalmaya neden olmuş olabilir. Hayvan Pulluğu: 2022'de 7, 2023'te 6, yani bir adetlik bir azalma gözlemlenmiştir. Bu makinenin azalmış olması, çiftçilerin modern mekanize makineleri tercih etmeye başlamasından kaynaklanıyor olabilir. Hayvanla çekilen pulluklar, daha çok geleneksel tarım yöntemlerini simgelerken, teknolojinin gelişmesiyle birlikte traktörle çekilen makinelerin tercih edilmesi artmıştır. Tınaz Makinası: 2022'de 100, 2023'te 98, yani 2 adetlik bir azalma yaşanmıştır. Tınaz makineleri, toprak işleme ve düzeltme amacıyla kullanılan araçlardır. Bu makinedeki düşüş, farklı toprak işleme yöntemlerinin yaygınlaşması ve daha modern makinelerin tercih edilmesiyle paraleldir. Özellikle, balya makineleri, gübrelik makineleri ve kimyevi gübre dağıtma makineleri gibi makinelerdeki artış, çiftçilerin daha verimli ve hızlı üretim yapmaya yönelik çabalarını göstermektedir. Bu makineler, tarımsal atıkları daha verimli bir şekilde değerlendirme ve gübre kullanımını optimize etme açısından önemli rol oynamaktadır. Çiftlik gübresi dağıtma makinelerindeki artış (2022: 63, 2023: 84) tarımda organik gübre kullanımının arttığını ve sürdürülebilir tarım uygulamalarına doğru bir eğilimin olduğunu ifade etmektedir. Organik gübre kullanımı, toprak sağlığını iyileştirebilir ve çevresel etkileri azaltabilir. Makine kullanımındaki genel artış, tarımda iş gücü verimliliğinin arttığını ve tarımsal süreçlerin daha hızlı ve etkili hale geldiğini göstermektedir. Özellikle kombine hububat ekim makineleri, diskli tırmıklar ve balya makineleri gibi makineler, zaman ve iş gücü tasarrufu sağlamakla birlikte, üretim süreçlerini hızlandırarak verimliliği artırmaktadır. Bu durum, tarım sektöründeki iş gücü azalışını ve makinelerin daha fazla tercih edilmesini açıklayabilir. Verilen veriler, tarım makinelerinin kullanımındaki artışın, verimlilik ve sürdürülebilirlik hedeflerine yönelmiş bir çaba olduğunu göstermektedir. 2022 ile 2023 yılları arasındaki artışlar, özellikle tarımsal üretimde verimliliği artırmaya yönelik modern makinelerin tercih edilmesinin bir göstergesidir. Diğer yandan, bazı makinelerdeki azalmalar, tarımda mekanizasyonun evrildiğini ve çiftçilerin daha etkili ve modern araçlara yöneldiğini ortaya koymaktadır. Bu tür gelişmeler, tarımın daha verimli, sürdürülebilir ve teknolojik olarak gelişmiş bir hale gelmesinin önünü açmaktadır.

Tablo 4'de Çiçekdağı ilçesinin mekanizasyon düzeyi göstergeleri verilmiştir. Yapılan hesaplamalar sonucunda 2022 yılında 35.97 traktör/1000 hektar olan 1000 hektarlık alana düşen traktör sayısı, 2023 yılında 38.74 traktör/1000 hektara yükselmiştir. Bu artış, tarımda kullanılan traktör sayısının arttığını ve dolayısıyla mekanizasyon seviyesinin yükseldiğini göstermektedir. Traktör sayısındaki artış, tarımda iş gücü verimliliğinin artmasını ve işlerin daha hızlı bir şekilde yapılmasını sağlayan teknolojik bir gelişim olarak değerlendirilebilir. Ancak bu artışın sürdürülebilirliği ve etkililiği, traktörlerin verimli kullanımıyla da doğrudan ilişkilidir.

2022'de traktör başına düşen arazi alanı 27,79 hektar iken, 2023'te bu oran 25,81 hektara gerilemiştir. Bu düşüş, daha fazla traktörün aynı arazi alanında faaliyet gösterdiğini ve dolayısıyla tarımsal üretimde daha fazla mekanizasyon kullanıldığını göstermektedir. Traktör başına düşen arazi alanının azalması, tarımda daha fazla iş gücü desteği ve daha verimli üretim süreçlerine işaret etmektedir.

2022 yılında traktör başına düşen güç 2,49 kW/ha iken, 2023'te bu değer 2,68 kW/ha'ya çıkmıştır. Traktörlerin gücündeki bu artış, tarımsal işlemlerin daha güçlü ve etkili makinelerle yapılacağını, daha geniş alanların daha kısa sürede işlenebileceğini ve üretim verimliliğinin artabileceğini gösterir. Bu artış, aynı zamanda tarım makinelerinin teknolojik gelişimine ve gücünün artırılmasına yönelik bir eğilimi işaret etmektedir.

Her iki yılda da ortalama traktör gücü 69 kW olarak sabit kalmıştır. Bu, kullanılan traktörlerin genel gücünde önemli bir değişim olmadığını ancak yine de traktör sayısındaki artış ve güç artışlarının, genel tarımsal mekanizasyon seviyesindeki gelişimi etkilemeye devam ettiğini göstermektedir. Traktörlerin güç seviyesinin sabit kalması, mevcut traktörlerin daha verimli ve güçlü makinelerle değiştirilmeye çalışıldığını veya mevcut makinelerin daha verimli kullanımına odaklanıldığını düşündürebilir.

Sonuç

2022 ile 2023 yılları arasında tarımsal mekanizasyon düzeyinde gözlemlenen değişiklikler, tarımsal üretimde daha fazla mekanizasyon kullanıldığını göstermektedir. Traktör sayısının artması ve traktör başına düşen arazi alanının azalması, temel tarımsal güç kaynağı olan traktörün mekanizasyon uygulamalarında önemli yer tuttuğunu göstermektedir. Ayrıca traktörlerin güçlerinde gözlemlenen artış, teknolojik gelişmelerin tarım makinelerine entegre edilerek üretim süreçlerinin hızlandığını ve daha verimli hale geldiğini göstermektedir. Bu tür gelişmeler, tarımsal üretimde mekanizasyonun giderek daha kritik bir rol oynadığını ve tarım sektöründeki modernleşme eğilimlerini yansıtmaktadır.

Beyanlar

Yazar Katkı Beyanı

C.F.: Veri toplama, araştırma, biçimsel analiz ve orijinal taslağın yazılması, Veri toplama ve araştırma

T.M.: Proje yönetimi, denetimi, kavramsallaştırma, metodoloji, inceleme ve düzenleme

Çıkar Çatışması

Yazarlar herhangi bir çıkar çatışması beyan etmemektedir.

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Effects of Different Organic Fertilizers on Yield and Yield-Related Characteristics in Black Cumin (*Nigella sativa* L.) Cultivation Under the Ecological Conditions of Tokat, Türkiye

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ABSTRACT

This research was carried out during the 2022 and 2023 growing seasons on Agricultural Research and Application Fields of Tokat Gaziosmanpaşa University. The study aimed to investigate the effects of different organic fertilizers and application rates on the yield and yield-related characteristics of black cumin (*Nigella sativa* L.). The experiment was designed using a split plot arrangement in a randomized complete blocks design with three replications. The main plots were assigned to five organic fertilizer types: Leonardite, Vermicompost, Solid Humus, Chicken Manure and Sheep Manure, while the subplots included in the same way in all fertilizer forms four fertilizer doses (0, 150, 300 and 600 kg/da). The study utilized "Çameli" variety, the only registered *Nigella sativa* L. variety in Turkiye. Key parameters examined over both years included plant height (cm), number of branches per plant (number), number of capsules per plant (number), number of grains per capsule (number), thousand seed weight (g), seed yield (kg/da). The results; revealed that the average plant height ranged from 39.76 to 54.33 cm, the number of branchers per plant, ranged from 6.22 to 6.35, the number of capsules per plant ranged from 13.43 to 14.88, the number of seed per capsule ranged from 98.56 to 104.00, thousand seed weight varied between 2.50 and 3.11 g, seed yield ranged from 135.26 to 135.41 kg/da. Statistically significant differences ($p<0.01$) were observed for all examined characteristics. Based on the two-year results the application of chicken manure at 300 kg/da was identified as the most effective treatment, significantly enhancing plant height, capsule number and thousand seed weight. This finding reveals that the use of organic fertilizer in black cumin cultivation is an important alternative for farmers who want to both increase yield and prefer a natural production method.

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Introduction

Black cumin (*Nigella sativa* L.) is an annual plant belonging to the Ranunculaceae family native to Southern Europe and Western Asia, across Mediterranean countries. It is commonly used in the Turkish food industry and cuisine to flavor and garnish bakery products (Ceylan, 1997). The harvested part of the is its black seeds, which mature within capsules. These seeds are 2-3 mm in length triangular in shape and characterized by a bitter taste (Toptas, 2008). According to Baydar (2013), black cumin grows upright with a taproot system, a herbaceous, light-colored stem and a height ranging from 20 to 60 cm. Its leaves are arranged alternately in a three-part structure along the main stem, with each main and lateral branch terminating in a flower. The flowers, which haves 5 pointed, light blue petals, and rich in nectar frequently visited by bees. In Turkiye, the cultivation area of black cumin expanded significantly from 2.299 da in 2012, to 83.915 da in 2023, representing an approximately 37 fold increase. Similarly, production volume rose from 161 tons in 2012 to 5.386 tons in 2023, marketing a 34 fold increase. Black cumin yield in Turkiye fluctuates annually, ranging from 70 to 119 kg per decare (TUIK, 2024). While black cumin production was limited to 5 provinces in 2012, it expanded to 27 provinces by 2023. According to 2023 data, the highest production was recorded in Uşak province, which contributed 2109 tons (32.7% of total production), followed by Burdur with 1.141 tons (17.7%), and Çorum with 762 tons (11.8%). The remaining 37.8% of production was distributed among other provinces. In 2023, Tokat province produced 30 tons of black cumin with an average yield 111 kg/da, 17th nationally black cumin production (TUIK, 2024). In recent years, increasinge global pollution has brought the importance of organic agriculture to the forefront, both internationally and nationally. To secure a larger share of the global market, countries are implementing laws and regulations aimed at promoting

organic agriculture. These efforts align with the goals of sustainable soil use reducing environmental pollution, and meeting the growing global demand for organic products.

In this context, the use of organic fertilizers plays a crucial role in reducing reliance on nitrogen and phosphorous based commercial fertilizers. Organic fertilizers have been shown to increase organic matter content improve water retention and nutrient uptake by plants, and positively impact the physical and chemical properties of soils (Bachman and Metzger, 2008). Most studies in this field focus on regional adaptations, yield and quality in relation tp different varieties and genotypes.

This study aimed to investigate the effects of 5 different organic fertilizers and 4 fertilizer doses on the yield and yield components of organically grown black cumin during the summer season in Tokat and its surrounding regions.

Materials and Methods

The research was carried out at the Agricultural Research and Application Fields of Tokat Gaziosmanpaşa University during the 2022 and 2023 growing seasons. The experimental site is situated at an altitude of 623 meters above sea level, between 40° 33' North latitude and 36° 47' East longitude. Soil analysis results of the experimental field during both years are given in Table 1.

The soils of the experimental field had a clayey-loam particle size distribution with a neutral pH. The soil is low in organic matter and available phosphorus, but sufficient in potassium. Additionally, the site has a high lime content.

The experiment utilized the Çameli variety of *Nigella sativa* L., a registered variety included in Turkey's national variety list. Çameli is a medium-sized variety with a thousand seed weight of 2.5 g and an average fixed oil content of 25% when processed via cold pressing. This variety was officially registered by the Eskişehir Transitional Zone Research Institute on April 8, 2014 (Turkish Ministry of Agriculture and Forestry, 2014).

The experimental design consisted of three randomized complete blocks, each divided into subplots to accommodate the split plot treatments. In the experiment, the main plots were allocated to the fertilizers, while the fertilizer doses were applied to the subplots. Planting was carried out manually on April 9, 2022 and April 15, 2023. Each plot was 4 meters long, consisting of 6 rows spaced 30 cm (total plot area 7.2 m^2), and 3.60 g of seed was planted in each row, following a planting density of 3 kg/da (Yilmaz et al., 2019). A 1 meter gap between plots and blocks were separated by 2 meters. Organic fertilizers used in the study were leonardite, vermicompost, solid humus, chicken manure and sheep manure. Four different fertilizer doses (0, 150, 300 and 600 kg/da) were applied in the same way in all fertilizer forms to all plots 10 days before planting. As part of the maintenance procedures, manual hoeing was conducted to control weeds when the plants had 3-4 leaves, and weed control was repeated every 15 days. Irrigation was performed using the sprinkler method, primarily during the early morning hours in summer and in dry periods with careful attention to soil moisture status. Harvesting took place manually on August 10, 2022, and August 15, 2023, when the plant capsules begun to turn brown. To minimize edge effects, 0.25 m from the top and bottom of the plots and one row from the sides were excluded from observation (3.5 x 0.30 x 4 = 4.2 m^2). The following parameters were assessed in black cumin plants: plant height (cm), number of branches per plant, number of capsules per plant, number of grains per capsule, thousand seed weight (g) and seed yield (kg/da). The data obtained were analyzed using variance analysis with the IBM SPSS 21.0 software (International Business Machines, Statistical Package for the Social Sciences). Duncan's multiple comparison test was applied to determine the differences between the means (Yurtsever, 1984).

Results and Discussion

The results of this research, which investigated the effects of different organic fertilizers and fertilizer doses on the yield and yield-related characteristics of the black cumin plant, are presented in Table 4, 5, 6, 7, 8 and 9.

Plant Height

The plant varied between 35.40-44.10 cm in 2022, with an average height of 39.76 cm. In 2023, the plant height ranged from 47.87 to 59.10 cm, with an average plant height of 54.33 cm. Over both years, the plant height varied between 41.64 and 51.60 cm, with an average of 47.05 cm.

Table 1. Soil analysis results of the trial area for 2022 and 2023.

Feature	2022	2023	Qualification Status	Source
Sand (%)	20.41	21.33		
Clay (%)	41.61	40.39	Clayey Loam	(Gee ve Bauder, 1986)
Silt (%)	37.98	38.28		
pH	7.0	7.0	Neutral	(Richards, 1954)
EC (mmhos/cm)	100	130	Low	(Richards, 1954)
Lime (%)	12.12	12.79	High	(Bayraklı,1986)
Organic Matter (%)	1.91	1.88	Low	(Walkley ve Black, 1934)
P_2O_5 (kg/da)	1.03	0.97	Insufficient	(Olsen ve Sommers, 1982)
K_2O (kg/da)	57.1	77.14	Sufficient	(Carson,1980)
Mg (ppm)	350.9	320.2	Sufficient	(Thomas,1982)
Zn (ppm)	0.39	0.57	Insufficient	(Lindsay ve Norvell, 1978)
Fe (ppm)	13.0	12.77	Sufficient	(Lindsay ve Norvell, 1978)
Mn (ppm)	5.11	5.32	Sufficient	(Lindsay ve Norvell, 1978)
Cu (ppm)	2.04	2.78	Sufficient	(Lindsay ve Norvell, 1978)
$CaCo_3$ (%)	8.6	9.8	Middle	(Thomas,1982)

According to the analysis results of the soil sample taken from 0-30 cm depth of the trial area, the soil of the trial area has a clayey-loamy structure, its average pH is neutral, it is poor in organic matter and available phosphorus, sufficient in potassium and rich in lime.

Table 2. Climate data for the trial area for 2022 and 2023.

Meteorological Data	Years	April	May	June	July	August	September	Average
Average Temperature (°C)	2022	15.1	15.3	20.9	21.0	25.6	20.5	19.58
	2023	12.4	15.6	20.3	22.3	25.2	20.2	19.33
	1951-2023	12.4	16.3	19.6	22.1	22.3	18.8	18.58
Average Rainfall (mm)	2022	29.6	34.7	84.1	0.1	1.1	28.6	29.70
	2023	118.3	52.8	74.5	41.3	2.2	9.2	49.72
	1951-2023	52.8	59.1	39.1	11.8	8.5	8.2	29.92

Source: Tokat Meteorology Directorate, 2023.

Table 3. Organic fertilizers applied in the experiment and their properties.

Serial No.	Fertilizers	Contents	By Mass (%)
1	Leonardite	Organic Matter	20 %
		Total Humic+Fulvic Acid	20 %
		Max Moisture	20 %
		pH	3.5 - 5.5
		Total Nitrogen	2 %
2	Vermicompost	Organic Matter	35 %
		Total Humic+Fulvic Acid	20 %
		Max Moisture	35 %
		pH	6.5 - 8.5
		Total Nitrogen	1.2 %
3	Solid Hummus	Organic Matter	40 %
		Total Humic+Fulvic Acid	5 %
		Max Moisture	20 %
		pH	7.9 – 9.9
		Total Nitrogen	2 %
4	Chicken Manure	Organic Matter	50 %
		Total Humic+Fulvic Acid	30 %
		Max Moisture	20 %
		pH	5.5 – 7.5
		Total Nitrogen	3.5 %
5	Sheep Manure	Organic Matter	40 %
		Total Humic+Fulvic Acid	5 %
		Max Moisture	20 %
		pH	7.5 – 9.5
		Total Nitrogen	2 %

The highest plant height in both years was obtained with chicken manure at a dose of 300 kg/da, while the lowest was obtained with leonardit at control (Table 4). The increased plant height in the second year can be attributed to higher spring rainfalls, which positively influenced plant height. Arabaci and Bayram (2005) also reported that plants benefiting from spring rain tend to grow taller. In different studies, plant height values in black cumin were observed as 32.5–55.8 cm by Faydaci (2019), 24.13-44.93 cm by Inan (2020), 30.23-35.77 cm by Can (2021), 17.1-33.5 cm by Bozdemir et al. (2022), and 38.73-47.80 cm by Karer and Beyzi (2022).

Number of Branches

The number of branches per plant was not significantly different for 2023. In 2022, the number of branches per plant varied between 4.97 and 7.43, with an average of 6.22 branches. In 2023, this number ranged from 5.30 to 7.23, with an average of 6.35 branches. Over two years, the number of branches per plant varied between 5.17 and 7.28, with an average of 6.28 branches. The higher average number of branches in 2023 can be attributed to increased spring rainfall in that year compared to 2022, which generally contributed to greater branching. The highest number of branches per plant in 2023 was obtained with the application of 300 kg/da chicken manure (Table 5). Branching in black cumin is a desirable trait up to a certain threshold, as both branch and capsule numbers positively influenced seed yield. Yilmaz (2008) reported that branching in black cumin is influenced by a both genotype and environmental factors, while Kucukemre (2009) highlighted that environmental conditions, planting density, soil nutrients, humidity, irrigation, rainfall and light all play a role in branching development. In other different studies, the number of branches values were obtained as 2.77-4.63 branches per plant by Kosar and Ozel (2018), 5.46-7.46 branches per plant by Sarac (2019), 4.2-3.2 branches per plant by Yilmaz et al. (2019), 3.5-6.2 branches per plant by Faydaci (2019), 2.67-5.30 branches per plant by Inan (2020), 5.85-9.00 branches per plant by Saglik (2020), 4.07-5.25 branches per plant by Can (2021), 3.92-5.18 branches per plant by Abay (2021).

Number of Capsules

The number of capsules per plant ranged from 8.10 to 21.47 in 2022, with an average of 13.43. In 2023, varied between 10.17 and 23.10, with an average of 14.88. Over two years, the number of capsules per plant varied between 9.14 and 22.29, with an average of 14.16.

Table 4. Plant heights (cm) of black cumin in different fertilizer and fertilizer dose applications in 2022, 2023 and two-year averages

Plant height (cm)					
2022					
Fertilizers/Doses	Control	150 kg/da	300 kg/da	600 kg/da	Average
Leonardite	35.40f	38.77cde	40.20bcd	37.20ef	37.89D
Vermicompost	35.70f	39.23cde	42.10ab	38.27de	38.83CD
Solid Humus	38.20de	40.17bcd	40.47bc	39.27cde	39.53BC
Chicken Manure	38.33de	43.57a	44.10a	40.07bcd	41.52A
Sheep Manure	38.57cde	39.60cd	43.20a	42.77a	41.04AB
Average	37.24D	40.27B	42.01A	39.52C	39.76B
2023					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	47.87g	52.27ef	52.63ef	53.34def	51.53C
Vermicompost	51.63f	53.85def	55.57cd	57.60abc	54.66B
Solid Humus	52.07f	52.70ef	52.50ef	54.30de	52.89C
Chicken Manure	52.23ef	58.10ab	59.10a	58.47ab	56.98A
Sheep Manure	51.83f	56.60bc	56.63bc	57.37abc	55.61AB
Average	51.13C	54.70B	55.29B	56.22A	54.33A
Two-Year Average					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	41.64j	45.52gh	46.42gh	45.27h	44.71C
Vermicompost	43.67i	46.54fgh	48.83cd	47.94def	46.74B
Solid Humus	45.14h	46.44gh	46.49fgh	46.79efg	46.21B
Chicken Manure	45.28h	50.83ab	51.60a	49.27cd	49.25A
Sheep Manure	45.20h	48.10de	49.92bc	50.07bc	48.32A
Average	44.18C	47.49B	48.65A	47.87B	47.05

The difference between values marked with the same letter is statistically insignificant.

Table 5. Branch numbers (number) in black cumin seed with different fertilizer and fertilizer dose applications in 2022, 2023 and two-year averages.

Number of branches (n/p)					
2022					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	5.27ef	5.97cde	5.57def	5.63c-f	5.61B
Vermicompost	5.33ef	7.33a	7.50a	7.57a	6.93A
Solid Humus	4.97f	5.73c-f	5.63c-f	5.77c-f	5.53B
Chicken Manure	5.10f	7.43a	7.33a	6.43bc	6.57A
Sheep Manure	5.03f	6.30bcd	6.93ab	7.57a	6.46A
Average	5.14B	6.55A	6.59A	6.59A	6.22A
2023^{ns}					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	5.33	6.10	7.10	6.33	6.22
Vermicompost	5.50	6.60	6.53	6.39	6.26
Solid Humus	5.67	6.33	6.17	6.03	6.05
Chicken Manure	5.90	7.13	7.23	7.03	6.82
Sheep Manure	5.30	6.77	6.89	6.60	6.39
Average	5.54 B	6.59 A	6.78 A	6.48 A	6.35 A^{+}
Two-Year Average					
Fertilizers/Doses	Control	150 kg/da	300 kg/da	600 kg/da	Average
Leonardite	5.30fg	6.04de	6.34cd	5.98def	5.91BC
Vermicompost	5.42efg	6.97abc	7.02abc	6.98abc	6.59A
Solid Humus	5.32fg	6.03de	5.90def	5.90def	5.79C
Chicken Manure	5.50efg	7.28a	7.28a	6.73abc	6.70A
Sheep Manure	5.17g	6.54bcd	6.91abc	7.09ab	6.42AB
Average	5.34B	6.57A	6.69A	6.54A	6.28

The difference between values marked with the same letter is statistically insignificant; ns : It is not significant at $p<0.01$ level; + : There is no statistically significant difference ($P<0.01$) between means shown with the same letters in the same row.

Table 6. Number of capsules (number) per plant in black cumin with different fertilizer and fertilizer dose applications in 2022, 2023 and two-year averages.

Number of capsules (n)					
2022					
Fertilizers/Doses	Control	150 kg/da	300 kg/da	600 kg/da	Average
Leonardite	8.10j	10.47ghi	11.23fgh	10.23hi	10.01E
Vermicompost	9.80i	14.40d	12.53e	12.17ef	12.23C
Solid Humus	8.23j	11.47efg	12.30ef	12.67e	11.17D
Chicken Manure	9.83i	21.43a	21.47a	18.77b	17.88A
Sheep Manure	10.03hi	18.20bc	18.23bc	17.10c	15.89B
Average	9.20C	15.19A	15.15A	14.19B	13.43B
2023					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	10.17j	13.83efg	13.15fgh	13.10gh	12.56C
Vermicompost	11.67hij	17.67c	15.20de	15.10ef	14.91B
Solid Humus	10.37j	12.60ghi	13.20fgh	12.60ghi	12.19C
Chicken Manure	11.63hij	21.43ab	23.10a	21.07b	19.31A
Sheep Manure	11.10ij	17.13cd	18.14c	15.42de	15.45B
Average	10.99C	16.53A	16.56A	15.46B	14.88A
Two-Year Average					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	9.14i	12.15g	12.19g	11.67gh	11.29E
Vermicompost	10.74h	16.04d	13.87e	13.64ef	13.57C
Solid Humus	9.30i	12.04g	12.75	12.64fg	11.68D
Chicken Manure	10.73h	21.43a	22.29a	19.92b	18.59A
Sheep Manure	10.57h	17.67c	18.19c	16.26d	15.67B
Average	10.09C	15.86A	15.86A	14.82B	14.16

The difference between values marked with the same letter is statistically insignificant.

The highest number of capsules per plant in 2022 was obtained with the 150 kg/da and 300 kg/da chicken manure, while in 2023, the highest number was obtained with 300 kg/da chicken manure (Table 6). The number of capsules in black cumin is directly correlated with branching, with more branches leading to a higher number of capsules (Baytore, 2011; Ozyilmaz et al, 2017). In previous studies were obtained number of capsules as 15.4-18.2 pieces/plant by Yilmaz et al. (2019), 2.87-4.70 pieces/plant by Can (2021) and 3.89-4.38 pieces/plant by Karer and Beyzi (2022).

Number of Seeds in Capsule

The number of seeds per capsule varied between 86.40 and 114.87 in 2022, with an average of 98.56. In 2023, ranged from between 86.87 to 115.03, with an average of 104.00. Over two years, the number of seeds in the capsule varied between 90.07-111.23, with an average of 101.28. The highest number of seeds in per capsule in 2022 was obtained with the application of 150 kg/da chicken manure, while in 2023, the highest number was obtained with 300 kg/da chicken manure (Table 7). The number of seeds per capsule is influenced by genotype and climatic conditions, and can also vary depending on the size of the capsules and seed. In previous studies, Faravani et al. (2012) were obtained values of 38.9-50.66 pieces/capsule, Inan (2020) 51.97-66.13 pieces/capsule, Saglik (2020) 28.50-55.07 pieces/capsule, Abay (2021) 80.21-69.77 pieces/capsule, Karer and Beyzi (2022) 64.94-75.52 pieces/capsule.

1000 Seed Weight

The thousand seed weight varied between 2.82 and 3.28 g in 2022, with an average of 3.11 g. In 2023, it ranged from 2.42 to 2.56 g, with an average of 2.50 g. Over two years, the thousand seed weight varied between 2.62 and 2.92 g, with an average of 2.80 g. The highest thousand seed weight in 2022 was obtained with the application of 150 kg/da chicken manure, while in 2023, the highest thousand seed weight was obtained with the application of 300 kg/da chicken manure (Table 8). The analysis conducted between 2022 and 2023 revealed, a general decrease in thousand seed weight. This decrease is consistent with the observation that the seeds in the capsules were larger in 2022, corresponding to higher thousand seed weight. The primary reasons for this reduction are believed to include the higher precipitation during the capsule formation period in 2023 compared to the previous year, as well as factors such as soil quality. In the second year of the study increased rainfall contributed to a higher weed population. Mubeen et al. (2009) stated one of the factors affecting thousand seed weights is weed density in planting areas, with an increase in weed density leading to a reduction in thousand seed weight. In the studies conducted by different researchers values were found; Tektas (2015) 2.90-2.40 g, Kosar and Ozel (2018) 1.81-3.16 g, Inan (2020) 2.50-2.64 g, Yilmaz et al. (2019) 2.1-2.8 g, Sarac (2019) 2.59-2.94 g, Faydaci (2019) 2.1-3.1 g, Can (2021) 2.45-3.35 g.

Seed Yield

Since black cumin seeds are primarily used as a medicinal and aromatic plant, seed yield is a key factor determining overall productivity. Seed yield is directly affected by the number of branches, capsules, seeds capsule and thousand seed weight (Yilmaz et al., 2019). Seed yield for 2022 varied between 74.73 and 209.31 kg/da with an average of 135.26 kg/da. Seed yield in 2023 varied between 101.11- and 184.96 kg/da, with an average of 135.41 kg/da.

Table 7. Number of seeds (number) per capsule in black cumin with different fertilizer and fertilizer dose applications in 2022, 2023 and two-year averages.

Number of seeds in the capsule (n)					
2022					
Fertilizers/Doses	Control	150 kg/da	300 kg/da	600 kg/da	Average
Leonardite	86.40j	94.17ghi	104.30c	96.40fg	95.32D
Vermicompost	90.70i	102.03cd	100.10de	96.13fg	97.24C
Solid Humus	93.27ghi	101.13cde	103.50cd	98.17ef	99.02B
Chicken Manure	92.43hi	114.87a	107.93b	102.53cd	104.44A
Sheep Manure	94.37gh	96.23fg	98.17ef	98.33ef	96.78CD
Average	91.43D	101.69B	102.80A	98.31C	98.56B
2023^{ns}					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	94.43	100.43	112.41	106.43	103.43
Vermicompost	91.20	112.27	115.03	112.15	107.66
Solid Humus	86.87	97.45	105.45	110.63	100.10
Chicken Manure	94.27	104.93	114.53	109.03	105.69
Sheep Manure	93.83	104.22	109.53	104.80	103.10
Average	92.12C	103.86B	111.39A	108.61AB	104.00A
Two-Year Average					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	90.42h	97.30e-h	108.36ab	101.42b-f	99.37B
Vermicompost	90.95h	107.15a-d	107.57abc	104.14a-e	102.45AB
Solid Humus	90.07h	99.29d-g	104.48a-e	104.40a-e	99.56B
Chicken Manure	93.35gh	109.90a	111.23a	105.78a-d	105.07A
Sheep Manure	94.10fgh	100.23c-g	103.85a-e	101.57b-f	99.94B
Average	91.78C	102.77B	107.10A	103.46B	101.28

The difference between values marked with the same letter is statistically insignificant; ns : It is not significant at p<0.01 level; + : There is no statistically significant difference (P<0.01) between means shown with the same letters in the same row.

Table 8. Thousand seed weights (g) of black cumin in different fertilizer and fertilizer dose applications in 2022, 2023 and two-year averages.

1000 seed weight (g)					
2022					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	2.82h	3.17a-e	3.13a-f	3.18a-d	3.08BC
Vermicompost	3.05def	3.15a-f	3.24abc	3.04def	3.12AB
Solid Humus	3.00fg	3.02efg	3.07def	2.87gh	2.99C
Chicken Manure	3.09c-f	3.28a	3.27a	3.26ab	3.23A
Sheep Manure	3.06def	3.26ab	3.16a-f	3.11b-f	3.15AB
Average	3.00C	3.17A	3.17A	3.09B	3.11A
2023					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	2.42f	2.53ab	2.49c	2.54ab	2.50B
Vermicompost	2.45ef	2.49c	2.49c	2.48cd	2.48C
Solid Humus	2.43ef	2.50c	2.51bc	2.53ab	2.49BC
Chicken Manure	2.46de	2.55a	2.56a	2.55a	2.53A
Sheep Manure	2.46de	2.49c	2.51bc	2.51bc	2.49BC
Average	2.44C	2.51B	2.52AB	2.53A	2.50B
Two-Year Average					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	2.62i	2.85a-d	2.81c-f	2.86a-d	2.79BC
Vermicompost	2.75fgh	2.82c-f	2.87abc	2.76e-h	2.80B
Solid Humus	2.72gh	2.76e-h	2.79d-g	2.70h	2.74C
Chicken Manure	2.78e-h	2.91ab	2.92a	2.91ab	2.88A
Sheep Manure	2.76e-h	2.88abc	2.84b-e	2.81c-f	2.82B
Average	2.72C	2.84A	2.84A	2.81B	2.80

The difference between values marked with the same letter is statistically insignificant.

Table 9. Seed yields (kg/da) of black cumin in different fertilizer and fertilizer dose applications in 2022, 2023 and two-year averages.

Seed yield (kg/da)					
2022					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	122.12fg	129.79ef	127.92efg	122.07fg	125.48C
Vermicompost	107.13h	141.82de	148.38d	153.46d	137.70B
Solid Humus	74.73i	125.85fg	121.95fg	117.62fgh	110.04D
Chicken Manure	107.45h	193.99b	209.31a	192.90b	175.91A
Sheep Manure	78.25i	114.92gh	147.22d	168.25c	127.16C
Average	97.94C	141.27B	150.96A	150.86A	135.26A
2023					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	105.39ij	127.06efg	136.43de	125.40g	123.57D
Vermicompost	101.11j	121.19gh	126.38fg	135.38def	121.02D
Solid Humus	108.65ij	144.05cd	137.75d	125.39g	128.96C
Chicken Manure	120.63gh	171.03b	184.96a	171.35b	161.99A
Sheep Manure	112.70hi	135.72def	152.38c	165.16b	141.49B
Average	109.70D	139.81C	147.58A	144.54B	135.41A^{+}
Two-Year Average					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	113.76k	128.43g-j	132.18fgh	123.74i-j	124.52D
Vermicompost	104.12l	131.51f-i	137.38ef	144.42de	129.36C
Solid Humus	91.69m	134.95fg	129.85f-i	121.51jk	119.50E
Chicken Manure	114.04k	182.51b	197.14a	182.13b	168.95A
Sheep Manure	95.48m	125.32hij	149.80d	166.71c	134.33B
Average	103.82C	140.54B	149.27A	147.70A	135.33

The difference between values marked with the same letter is statistically insignificant. $^{+}$There is no statistically significant difference ($P<0.01$) between means shown with the same letters in the same row.

Over two years, seed yield varied between 91.69 and 197.14 kg/da, with an average of 135.33 kg/da. The highest seed yield for both yields was obtained with the application of chicken manure at a fertilizer dose of 300 kg/da (Table 9). Fertilizer application had a significant impact on seed yield, with chicken manure resulting in higher yields compared to other fertilizer types. Furthermore, increasing fertilizer doses generally led to higher seed yields. That the effectiveness of chicken and sheep manure, in increasing seed yield can be attributed to their high nutrient content compared to other organic fertilizers. In previous studies, seed yield was obtained as 71.90-118.77 kg/da by Tektas (2015), 117.7-191.3 kg/da by Yilmaz et al. (2019), and 97.60-117.36 kg/da by Abay (2021).

Conclusion

The long-term use of chemical fertilizers disrupts the biological balance of the soil and can lead to significant issues in the cultivation of medicinal and aromatic plants. Therefore, the application of organic fertilizers is crucial in the cultivation of important crops like black cumin, as it helps promote sustainable agricultural practices by protecting soil health and ensuring the production of products that are safe for human consumption. In this study, which evaluated the effect of different organic fertilizers and fertilizer doses on black cumin cultivation, it was observed that organic fertilizers generally had a positive effect. Chicken manure and a fertilizer dose of 300 kg/da were the most prominent applications.

Black cumin is a medicinal and aromatic plant, with its seeds being the primary product. Therefore, seed yield is a critical factor in its cultivation. In this study, it was observed that the different organic fertilizer treatments has a significant impact on seed yield. The results demonstrated that organic fertilizer applications substantially increased black cumin seed yield. This finding reveals the importance of using organic fertilizers in black cumin cultivation, offering an effective alternative for farmers seeking to increase yields while opting for natural production methods.

Declarations

Author Contribution Statement

Abdulkadir Acar: Conducted the study, data collection, review, formal analysis, and writing the original draft. Yasin Bedrettin Karan: Management, supervision, review, editing, and statistical analysis of the study.

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Conflict of Interest

"We declare that the authors have no conflict of interest."

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Characterization of Some Hybrid Potato (*Solanum tuberosum* L.) Genotypes

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ABSTRACT

This research was carried out to contribute to the determination of variety candidates with suitable characteristics among 714 clones belonging to 12 hybrid potato families obtained by hybridization breeding method. The research was carried out under polycarbonate greenhouse conditions within the TUBITAK-TOVAG project no. 113O928. As a result of the research, the average emergence time of hybrid families was determined as 10.92 days, plant height as 55.24 cm, and number of main stems as 1.75. It was determined that 97.60% of the hybrid families were yellow, 2.40% were red and 75.85% were light yellow, 13.05% were yellow and 11.10% were white of tuber inner colour. The average tuber yield per hill of the 12 hybrid families in the study varied between 133.93-410.97 g/hill and the average was 267.24 g/hill. The number of tubers per plant of these hybrid families varied between 5.99-15.03 with an average of 9.97 tubers per plant, and the average tuber weights varied between 12.58-37.37 g with an average of 24.77 g. Out of 714 clones analyzed, 23 clones were found to be superior in terms of the criteria in the early selection process. These 23 clones showing superior characteristics were evaluated as promising clones in the advanced stage of the breeding processes.

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Bazı Melez Patates (*Solanum tuberosum* L.) Genotiplerinin Karakterizasyonu

MAKALE BİLGİSİ

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ÖZ

Bu araştırma, melezleme ıslahı yöntemi ile elde edilen 12 melez patates ailesine ait 714 klon arasından uygun özelliklere sahip çeşit adaylarının belirlenmesine, erken dönem seleksiyonlarının katkı sağlaması için yürütülmüştür. Araştırma 113O928 nolu TÜBİTAK-TOVAG projesi kapsamında polikarbon sera şartlarında yürütülmüştür**.** Araştırma sonucunda melez ailelerinin ortalama çıkış süresi 10,92 gün, bitki boyu, 55,24 cm, ana sap sayısı 1,75 adet olarak belirlenmiştir. Melez aileleri, %97,60 sarı, %2,40'ı kırmızı benekli kabuk rengine sahip iç rengi bakımından ise %75,85'i açık sarı, %13,05'i sarı ve %11,10'u beyaz olduğu belirlenmiştir. Çalışmada yer alan 12 melez ailesinin ocak başına ortalama yumru verimleri 133,93-410,97 g/ocak arasında değişmiş olup, ortalama 267,24 g/ocak şeklinde gerçekleşmiştir. Söz konusu melez ailelerinin bitki başına yumru sayıları 5,99-15,03 arasında değişmiş olup, ortalama 9,97 yumru/ocak olmuş, ortalama yumru ağırlıkları ise 12,58-37,37 g arasında ve ortalaması 24,77 g olarak gerçekleşmiştir. İncelenen 714 klondan 23'ü ele alınan kriterler bakımından daha üstün bulunarak, yapılan erken dönem seleksiyonlarında öne çıkmıştır. Üstün özellik gösteren bu 23 klon, devam eden ıslah süreçlerinin ileri aşamasında ümit var klon olarak değerlendirilmişlerdir.

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Giriş

Patates (*Solanum tuberesum* L.), *Solanaceae* familyasından, *Solanum* cinsine ait, yumruları tüketilen bir bitkidir. Patates günümüzde, karbonhidrat kaynağı olarak tahıl grubu bitkilerden sonra insan gıdası olarak en çok tüketilen besin maddesidir. Patates dünyada 161 ülkede aktif bir şekilde yetiştirilmektedir. Geniş kullanım alanı, yüksek verimli olması ve zengin besin içeriği sayesinde temel gıdalardan biri olarak talep görmeye devam etmektedir. Patates yumrusunda karbonhidratlar, protein ve vitaminlerin (C ve B grubu) yanı sıra mineral maddeler de (K, Mn, Mg, Fe, Cu, P) bulunmaktadır (Çalışkan ve ark., 2020). Haşlanmış 100 g patates yumrusu, bir insanın ihtiyaç duyduğu günlük enerjinin %4-6'sını, protein ihtiyacının %5'ini, günlük potasyum ihtiyacının %15'ini, günlük C ve B vitamini ihtiyacının ise %16'sını karşılamaktadır (De Haan ve ark., 2019). Patates, açlık ve yetersiz beslenme ile karşı karşıya olan birçok toplum için, beslenme sorununun çözümüne katkı verebilecek önemli tarımsal ürünlerin başında gelmektedir (Devaux ve ark., 2014; Hussain, 2016).

Patates bitkisinin ilk defa Peru'da bulunan And dağları bölgesinde kültüre alındığı bilinmektedir (Ames & Spooner, 2008). Patatesin Türkiye'ye 1850'li yıllarda Balkanlar üzerinden Marmara bölgesinin Çatalca-Kocaeli bölgesinde yetiştirilmeye başlandığı bildirilmekle birlikte, 1870'li yıllardan itibaren Kafkasya ve Rusya üzerinden Karadeniz ve Doğu Anadolu bölgelerine getirildiği ve buralarda yetiştiriciliğinin yapılmaya başlandığı da belirlenmiştir (İlisulu, 1986). Türkiye'de 2023 yılında yaklaşık 150 bin da alanda patates dikimi yapılmış olup, 5,7 milyon ton üretim gerçekleştirilmiş, dekara verimi 3777 kg/da olarak belirlenmiştir (Anonim, 2024). Ülkemizde üretimi yapılan çeşitler içerisinde yerli tescilli çeşitlerin sınırlı sayıda olması nedeniyle, yurtdışından ithal edilen orijinal kademedeki tohumluklar, hala ciddi boyutta yer almaktadır (Yılmaz, 2016; Yılmaz ve ark., 2016). Türkiye'nin patateste dışa bağımlılığı, uzun yıllardan beri giderilmeye çalışılsa da son yıllarda geliştirilen yerli çeşitlerimizin henüz yabancı çeşitlerle yüksek düzeyde rekabet etme şansı yakalayamadığı anlaşılmaktadır. (Öztürk &Yıldırım, 2018; Öztürk & Yıldırım, 2019)

Patateste çeşit geliştirme süreci, birbirini izleyen aşamalara bağlı olup, genellikle melezleme yöntemi ya da mutasyon ıslahı ile başlamakta olup, klonal seleksiyon yöntemi ile devam etmektedir (Yılmaz ve ark., 2013). Seleksiyon sürecinin ardından lokasyon denemeleri yapılmakta olup bu aşamayı ileri generasyon seleksiyon süreci takip etmektedir. Patateste ıslah süreci bu aşamaların sırasıyla takibi ile 10-12 yıl kadar sürebilmektedir. Patates ıslahında izlenen yol onu diğer bitki ıslah süreçlerinden ayırır. Bu durumun temel nedeni kültürü yapılan patateslerin vejatatif yolla çoğaltılması ve genotiplerin autotetraploid yapıda olmasıdır (Tarn ve ark., 1997). Patates ıslahı uzun bir süreci gerektirmekte olup, yeni bir çeşit geliştirilirken 40'tan fazla niteliğin göz önüne alındığı bildirilmektedir (Gebhardt, 2013). Bu niteliklerden bazıları yumru verimi, kalite özellikleri, biyotik ve abiyotik stres şartlarına dayanıklılık başlıkları altında yer almaktadır (Slater ve ark., 2014). Patateste, kısa sürede ve istenen özelliklere sahip yeni bir çeşit elde etmek için, ıslahçının kullanacağı ebeveynlerin üstün özelliklere sahip olması, istediği özellikleri taşıması, uygulanacak ıslah yöntemini, seleksiyon programının yeri ve zamanının iyi planlanması gerekmektedir (Kuşman, 2006).

Patates ıslahında melezleme sonucu elde edilen tohumlar sera şartlarında mini yumrular üretilmesinde kullanılır. Bu süreçte yetişen genotipler, sonraki dönemlerde yetiştirilmesi planlanan genotiplerin özelliklerini tam yansıtmadıkları için, bu dönemde yapılan seleksiyon sert değildir. Erken dönemde, derin göz ve yumru şekli gibi özellikler dikkate alınarak pozitif seleksiyon önerilmektedir (Zarka & Douches, 2015). Bu dönemde bitkiyi tanımayı sağlayan karakterizasyon işlemleri seleksiyonun etkinliğini artırmaktadır. Bu süreç karakterizasyon çalışmasının yanı sıra, seleksiyon kriterlerini belirlemek ve etkin bir seleksiyon yapmak için değerlendirilir (Love ve ark., 1997). Seleksiyon sürecinde, ocak başına yumru sayısı, yumru şekli, ocak başına yumru verimi, ortalama yumru ağırlığı, kuru madde içeriği, yumru iç rengi, kabuk rengi, kabuk düzgünlüğü kriterlerine yoğunlaşılmaktadır (Yılmaz ve ark., 2016). Patates ıslahına melezleme ile başlanabilmektedir. Melezle için bitkinin morfolojisinin iyi bilinmesi ve melezleme tekniklerinin iyi uygulanması gerekmektedir. Melezlemenin önemli kriterlerinden biri ebeveynler arasındaki uyumdur. Melezlemeden daha başarılı ve iyi sonuçların alınması için melezleme işleminin sabahın erken saatlerinde, serin ve yüksek rakıma sahip yerlerde ise, polikarbon ya da tül seralarda yapılması uygun bulunmaktadır. Melezlemenin yüksek sıcaklıklarda yapılması, başarıyı azaltırken, gece gündüz sıcaklığı arasındaki farkın yüksek olduğu veya 15-19 ^{0}C gibi sıcaklık şartlarında ve uzun günlerde yapılan melezlemelerdeki sonuçlar daha başarılı olmaktadır. Bunun yanı sıra bitkinin sentezlemiş olduğu gibberellik asit bitkinin çiçek oluşturması ve meyve bağlamasında önemli rol oynamaktadır (Sleper & Poehlman, 2006; Yılmaz ve ark., 2016).

Bu araştırma, yeni ve yerli patates çeşitlerinin geliştirilmesi amacıyla yürütülen TÜBİTAK-TOVAG 113O928 nolu proje kapsamında yapılan melezleme programlarından elde edilen tohumlardan oluşturulan fide generasyonu sonucundaki bazı klonlarda, makroskobik gözlem ve ölçümlere dayalı birtakım bitkisel özelliklerin karakterize edilerek, erken generasyon seleksiyonlarına katkı sağlanması amaçlanmıştır.

Materyal ve Yöntem

Bu çalışma 2016 vejetasyon döneminde 113O928 nolu TÜBİTAK-TOVAG projesi kapsamında Gaziosmanpaşa Üniversitesi, Tarla Bitkileri Bölümü, polikarbon sera şartlarında, melezleme ıslahı yöntemi ile elde edilen, 12 melez ailesinden, 714 adet klon seçilerek yürütülmüştür. Polikarbon sera ortamında, 26 litre hacimli saksılar kullanılmış olup, her bir saksı için torf 2/3 ve perlit 1/3 karışımı hazırlanmıştır. Her bir saksıya bir adet yumru dikimi ile NPK (15-15-15) verilmiş olup, bitki gelişim süresince mono amonyum fosfat, potasyum nitrat, magnezyum sülfat, kalsiyum nitrat, amonyum nitrat ve gerekli mikro besin elementleri de uygulanıp (Roy ve ark., 2016), bitkinin sağlıklı gelişimi sağlanmaya çalışılmıştır.

Çalışmada; çıkış süresi, bitki boyu, bitkide ana sap sayısı, bitki başına yumru sayısı, bitki başına yumru verimi, ortalama yumru ağırlığı, kabuk rengi ve iç rengi değerleri incelenmiştir. Çalışma neticesinde yapılan gözlem ve ölçümler Tohumluk Tescil Sertifikasyon Merkezinin (TTSM) belirlediği, tarımsal değerleri ölçme denemeleri teknik talimatları esas alınarak yapılmıştır (Anonim, 2014). Ayrıca çalışmada yapılan gözlem ve ölçümler literatüre dayanarak yapılmıştır (Fehr & Hadley, 1980; Munzert & Scheidt, 1989; Poehlman & Sleeper, 1995). Çalışmada kullanılan melez ailelerine ait genel özellikler Çizelge 1 ve Çizelge 2'de verilmiştir.

Bulgular ve Tartışma

Çıkış Süresi

Melez ailelerinin çıkış süresi 8-23 gün arasında değişmiş, ortalama 10,92 gün olarak belirlenmiştir (Çizelge 3). Melez aileleri içerisinde en geç çıkış süresine sahip melez ailesi 23 gün ile 8. melez ailesi olurken, bunu 15 gün ile 6. ve 7. melez ailesi, 14 gün ile 5. melez ailesi takip etmiştir. Diğer melez ailelerinde ise çıkış süresi 8 gün olarak belirlenmiştir (Çizelge 3). Patateste çıkış süresi birçok unsurdan dolayı etkilenmektedir. Kullanılan tohumluğun fizyolojik yaşı, iriliği, dikimin yapıldığı derinlik, toprağın yapısı, sıcaklık ve toprağın nem durumu ve patates çeşidinin genetik yapısı çıkış süresini etkileyen faktörlerdir (Yıldırım & Yıldırım, 2002). Patateste fizyolojik olarak daha yaşlı tohumluklarda sürgün sayısı artmakta olup, bu durum erken çıkışlar üzerinde etkili olmaktadır (Kara ve ark., 2002).

Bitki Boyu

Melez ailelerine ait bitki boyları incelendiğinde, 18,25 cm ile 114,02 cm arasında varyasyon gösterdiği belirlenmiş olup, melez ailelerinin ortalama bitki boyu 55,24 cm olarak belirlenmiştir (Çizelge 3). En yüksek bitki boyu 114,02 cm ile 11. melez ailesinde belirlenirken, en düşük bitki boyu 18,25 cm ile 3. melez ailesinde belirlenmiştir. Melez aileleri ortalamasının üzerinde bitki boyuna sahip olanlar; 7., 8., 10., 11. ve 12. melez aileleri olarak belirlenmiştir (Çizelge 3). Bitki boyu morfolojik özelliklerden biri olup, bitkinin büyüme hareketini belirlemektedir. Genetik özellikler, yetiştirildiği toprağın içermiş olduğu besin maddeleri, tohumluğun gücü ve yetiştirildiği çevrenin koşulları bitki boyu üzerinde etkili olmaktadır (Bastem, 2023). Bitki boyu bir çeşit özelliğidir, bitki dikim sıklığından, gün uzunluğundan, sıcaklıktan, nispi nemden, toprağın bitki besin elementi içeriğinden ve suyun kullanımından etkilendiği bilinmektedir. Çeşitlerin ve hatların bitki büyüme şekilleri bakımından farklılıklarının olması bitki boylarının da farklılık oluşturmasına neden olmaktadır (Günel ve ark., 1991). Ayrıca, genetik olarak geçci ve erkenci çeşitler karşılaştırıldığında, geççi çeşitlerin yaprak alan indekslerinin daha fazla ve daha uzun boylu oldukları bildirilmiştir (Yılmaz & Tuğay, 1999). Çeşit özelliğinin bitki boyu üzerindeki etkisine ek olarak gün uzunluğu, toplam sıcaklık, vejetasyon dönemindeki toplam yağış ve toprağın azot içeriğinin de etkisinin olduğu çeşitli araştırıcılar tarafından bildirilmiştir (Çalışkan & İncekara, 1980; Yılmaz & Tuğay, 1999).

Çizelge 1. Çalışmada Yer Alan Patates Melez Kombinasyonları
Table 1. Potato Hybrid Combinations Included in the Study

Kombinasyon No	Ana	Baba	Kombinasyon No	Ana	Baba
1	A3/110	A2/11	7	Başçiftlik Beyazı	A13/1
2	A8/34	A13/1	8	Başçiftlik Beyazı	Megusta
3	T4/4	T6/28	9	Başçiftlik Beyazı	Van Gogh
4	A2/11	Melody	10	Aleddiyan Sarısı	Megusta
5	A7/12	Van Gogh	11	Aleddiyan Sarısı	A2/11
6	A3/223	Megusta	12	T4/4	A2/11

Çizelge 2. Denemede Yer Alan Melez Aileleri Yumrularına Ait Bazı Özellikler
Table 2. Some Characteristics of Tubers of Hybrid Families Included in the Experiment

KN	YS	Yumru Şekli			Kabuk Düzgünlüğü			Dış Kabuk Rengi		İç Rengi			
		Y	O	U	D	P	OR	S	M	S	KS	K	B
1	142	43	80	19	35	15	32	120	22	90	8	38	6
2	28	15	10	3	11	17	-	28	-	24	-	4	-
3	14	-	9	5	10	4	-	14	-	13	-	1	-
4	48	18	18	12	41	5	2	46	2	47	-	1	-
5	45	16	25	4	15	30		40	5	32	3	10	-
6	87	59	-	28	56	21	10	67	20	71	3	13	-
7	181	79	102	-	119	62	-	145	36	29	80	72	-
8	102	17	85	-	12	90	-	84	18	66	29	7	-
9	30	6	24	-	24	6	-	21	9	19	-	11	-
10	19	6	8	3	2	11	-	8	5	19	-	-	-
11	136	67	69	-	64	68	4	81	55	-	-	-	-
12	36	-	19	17	25	5	6	34	2	-	30	4	2

KN: Kombinasyon No; YS: Yumru sayısı; Y: Yuvarlak; O: Oval; U: Uzun; D: Düzgün; P: Pürüzlü; OR: Orta; S: Sarı; M: Mor; KS: Koyu Sarı; K: Krem; B: Beyaz

Çizelge 3. İncelenen melez ailelerine ait morfolojik özellikler
Table 3. Morphological features of the studied hybrid families

Melez Ailesi	İncelenen Klon Sayısı	Çıkış Süresi (gün)	Bitki Boyu Ort. (cm)	Ana Sap Sayısı (adet/bitki)	Kabuk Rengi (%)		Et Rengi %		
					Sarı	Kırmızı Benek	Açık Sarı	Sarı	Beyaz
1	142	8	31,00	1,53	96,91	3,09	87,63	2,06	10,31
2	28	8	37,00	1,00	100,00	0,00	78,57	0,00	21,43
3	14	8	18,25	1,25	100,00	0,00	90,91	0,00	9,09
4	48	8	26,58	1,41	97,67	2,33	83,72	9,30	6,98
5	45	14	32,88	1,31	93,33	6,67	86,67	0,00	13,33
6	87	15	28,21	1,35	98,39	1,61	91,94	6,45	1,61
7	181	15	101,81	2,29	91,38	8,62	60,92	36,78	2,30
8	102	23	77,43	1,88	100,00	0,00	62,00	37,00	1,00
9	30	8	39,00	2,40	100,00	0,00	46,15	0,00	53,85
10	19	8	89,83	2,00	100,00	0,00	62,50	37,50	0,00
11	136	8	114,02	2,85	96,99	3,01	90,23	6,77	3,01
12	36	8	66,85	1,78	96,55	3,45	68,97	20,69	10,34
Ortalama		10,92	55,24	1,75	97,60	2,40	75,85	13,05	11,10

Ana Sap Sayısı

Melez ailelerine ait ortalama ana sap sayısı 1,75 adet/bitki olarak belirlenirken, ana sap sayısı incelen melez ailelerinde 1,00-2,85 adet/bitki arasında değişim göstermiştir (Çizelge 3). En fazla ana sap sayısına sahip melez ailesi 2,85 adet/bitki ile 11. melez ailesi olurken, bunu 2,40 adet/bitki ile 9. melez ailesi, 2,29 adet/bitki ile 7. melez ailesi ve 2,00 adet/bitki ile 10. melez ailesi takip etmiştir. En düşük ana sap sayısına sahip melez ailesi ise 1 adet/bitki ile 2. melez ailesi olmuştur (Çizelge 3). Patateste ana sap sayısı, yumru iriliği, yumru üzerindeki göz sayısı ve yumrunun dormansi dönemine bağlıdır. Bu sebeple, ana sap sayısının belirlenmesi yumru iriliği ve ortalama yumru ağırlığının öngörüsü için belirleyici bir kriterdir (Arıoğlu, 1990; Esendal, 1990). Toprak sıcaklığı, toprak sıkışıklığı, topraktaki nem miktarı, azot uygulamaları ve gün uzunluğu da ana sap sayısını etkileyen faktörler arasında yer almaktadır (Marinus & Bodlaender, 1975; Fahem & Haverkort, 1988; Günel & Karadoğan, 1991).

Kabuk Rengi ve Yumru İç Rengi

Melez ailelerinin kabuk renkleri incelendiğinde ağırlıklı olarak ortalama %97,60 oranında sarı renkli ve %2,40 kırmızı benek yumrular tespit edilmiştir. Kırmızı benek tespit edilen melez aileleri; 1., 4., 5., 6., 7., 11. ve 12. melez aileleridir (Çizelge 3). Melez ailelerinin yumru iç renkleri incelendiğinde; açık sarı renklilerin ortalaması %75,85 olarak belirlenirken, sarı renkli olanlar %13,05 iken beyaz ernkli olanlar ise %11,10 şeklinde belirlenmiştir (Çizelge 3). En yüksek oranda açık sarı yumru iç rengine sahip olan melez ailesi %91,94 ile 6. melez ailesi olurken, en düşük oranda açık sarı iç rengine sahip melez ailesi %46,15 ile 9. melez ailesi olmuştur (Çizelge 3). Ortalama en yüksek sarı iç rengine sahip olan melez ailesi %37,50 ile 10. melez ailesi iken, 2., 3., 5. ve 9. melez ailelerinde sarı iç renkli yumru belirlenememiştir. Beyaz iç rengi oranı en yüksek 9 numaralı melez ailesinde belirlenirken, 10 numaralı melez ailesinde ise beyaz iç rengi belirlenememiştir (Çizelge 3). Patateste iç renginin kalıtım derecesinin yüksek olmasına rağmen, sentezlenen renk pigmentleri ve çeşitli kimyasal maddelere göre şekillendiği bilinmektedir. Bu bileşenlerden karotenoidler, flavonoid-fenolik bileşiklerin patatesin iç rengi ile ilişkili olduğu, yapılan araştırmalarda yüksek karotenoid içeren çeşitlerin sarı iç rengi yoğunluğunun arttığı, antosiyanin miktarının yüksek olduğu çeşitlerin ise kırmızı ve mor iç renginin hâkim olduğu, flavonoid miktarı yüksek olan patateslerin ise iç renklerinin beyaz olduğu tespit edilmiştir (Jansen ve ark., 2001; Lu ve ark., 2001; Brown, 2005; Hale, 2005).

Bitki Başına Yumru Verimi

Melez ailelerinin ortalama yumru verimi 133,93-410,97 g/saksı arasında değişim göstermiş olup, ortalama 267,24 g/saksı olmuştur. Yumru verimi bakımından ortalamanın üzerinde olan melez aileleri 7., 8., 11. ve 12. melez aileleridir. Bu melez ailelerinin ortalama yumru verimleri sırası ile 399,10 g, 332,12 g, 388,61 g ve 410,97 g/saksıdır (Çizelge 4). 7. melez ailesinde saksı başına yumru veriminin değişim sınırları 9,00- 1747,00 g/saksı arasında olup, öne çıkan klonlar 509-38 ve 479 numaralı klonlardır. 8. melez ailesinin saksı başına yumru verimleri 12,00- 1252,00 g/saksı arasında değişmiştir. Bu melez ailesinde öne çıkan klonlar; 351- 33 ve 226 numaralı klonlar olmuştur. 11. melez ailesinde yumru verimleri 40,00-845,00 g/saksı arasında değişim göstermiş, yumru verimi bakımından öne çıkanlar; 187, 535 ve 336 numaralı klonlar olmuştur (Çizelge 4). 12. melez ailesinde ise yumru verimleri 13,00- 1078 g/saksı arasında değişim göstermiş olup; 174-156 ve 705 numaralı klonların saksı başına daha yüksek yumru verimi sağladıkları görülmüştür (Çizelge 4). Yumru verimi, üretimi yapılan patates çeşidinin genetik özelliklerine, bakım işlemlerine, yetiştiriciliğin yapıldığı ekolojik koşullara ve yıllara göre değişkenlik gösterebilmektedir (Yılmaz & Karan, 2011). Yumru verimi genotip x çevre intreaksiyonuna karşı oldukça hassastır. Bir ekolojide yüksek verimli olan bir patates genotipi farklı bir ekoloji de düşük verimli olabilir (Dede, 2004). Patetesin çevre koşullarına karşı duyarlılığın fazla olduğu bilinmekte olup aynı çeşitin farklı ekolojilerde yumru verimi dışında farklı morfolojik yapı ve farklı kalite özellikleri gösterdiği bilinmektedir (Vayda, 1994). Yumru verimleri ayrıca, ana sap sayısı, bitki başına yumru sayısı ve ortalama yumru ağırlığına bağlıdır. Bu özelliklerde de genetiğin payı büyüktür. Bu yüzden seleksiyon çalışmalarında verim ve verimi doğrudan etkileyen

faktörlerin kullanımı kaçınılmazdır. Sera koşullarında erken dönemde yürütülen bu çalışmada yumru verimi patatesin birçok faktöre duyarlı olması sebebi ile çeşitlilik göstermiştir.

Bitki Başına Yumru Sayısı

Melez ailelerinin bitki başına yumru sayısı ortalaması 9,97 adet şeklinde belirlenmiştir. Bitki başına yumru sayısı ortalamaları 5,99-15,03 adet/bitki arasında değişim göstermiştir (Çizelge 4). Bitki başına yumru sayısı bakımından melez aileleri ortalamasının üzerinde olanlar; 7, 8, 9, 10, 11 ve 12 numaralı melez aileleridir. 7. melez ailesinin bitki başına yumru sayısının değişim sınırları 1-40 adet arasında olup, 462-115 ve 106 numaralı klonlar en yüksek yumru sayısına sahip klonlardır (Çizelge 4). 8. melez ailesinin bitki başına yumru sayısındaki değişim sınırları 1-29 adet/bitki olarak belirlenmiş ve en yüksek bitki başına yumru sayıları 314-94 ve 128 numaralı klonlardan elde edilmiştir. 9. melez ailesinde bitki başına yumru sayıları 2-39 adet/bitki arasında değişmiş olup, öne çıkan klon numaraları 321-195 ve 327 numaralı klonlardır. 10. melez ailesinde bitki başına yumru sayıları 2-32 adet/bitki arasında değişmiş olup öne çıkan klonlar 20-50 ve 22 numaralı klonlardır. 11. melez ailesinde bitki başına yumru sayısı 1-32 arasında değişmiş olup, 499-461 ve 500 numaralı klonlar en yüksek bitki başına yumru sayısına sahip klonlardır. 12. melez ailesinde ise bitki başına yumru sayısı 3-33 adet/bitki arasında değişmiş olup, öne çıkan klonlar 189-21 ve 42 numaralı klonlar olmuştur (Çizelge 4). Patates yumruları, sapın toprak altında gelişen uzantıları olan stolonların uçlarında oluşur ve toprak altı depo organı olarak tanımlanır (Cutter, 1992). Yumru sayısı patates ıslah sürecinde üstün özellikli bireylerin belirlenmesi başta olmak üzere verim ve istenilen kalite kriterlerini açığa çıkması bakımından ıslah sürecinin temelidir (Acquaah, 2007). Ocaktaki yumru sayısı, ana sap sayısı ve oluşan yumru sayısına bağlıdır. Yumru sayısındaki artış, ocak başına yumru verimindeki artışı, buna bağlı olarak dekara yumru verimindeki artışı doğrudan etkilemektedir. Genel olarak, ana sap sayısı, ocak başına yumru sayısını etkileyen çeşit özelliklerindendir (Yalçın & Tunçtürk, 2018). Yumru sayısı, genetik yapıdan da etkilenmektedir ayrıca tohumluğun kalitesi, tohumluk yumrunun iriliği ve ekolojik şartlara görede değişmektedir (Burton, 1981). Bitki başına yumru sayısının oluşumunda toprağın tekstür ve strüktürü, su tutma kapasitesi, toprak sıcaklığı, gün uzunluğu, atmosfer sıcaklığı ve gece-gündüz sıcaklıkları arasındaki farklılıklar da etkilidir (Wurr ve ark., 2001). Eşit koşullar altında yürütülen bu çalışmada, yumru verimini de doğrudan etkileyen özelliklerden biri olan bitki başına yumru sayısı kriteri bu yüzden seleksiyon çalışmalarında dikkate alınan bir kriterdir.

Ortalama Yumru Ağırlığı

Melez ailelerinin yumru ağırlığı ortalaması 24,77 g olarak belirlenmiş, ortalama yumru ağırlıkları 12,58- 37,37 g arasında değişim göstermiştir. 3., 5.,7.,8.,11. ve 12. melez ailelerinin ortalama yumru ağırlığı, genel ortalamanın üzerinde olduğu belirlenmiştir. 3. melez ailesinde ortalama yumru ağırlıkları 7,00- 59,43 g arasında değişim göstermiş olup, en yüksek ortalama yumru ağırlığı 25-14 ve 24 numaralı klonlara aittir ve 3. melez ailesinin genel ortalama yumru ağırlığı 28,19 gramdır. 5. melez ailesinin ortalama yumru ağırlığı 26,11 gramdır ve ortalama yumru ağırlığı 6,00 g ile 57,60 g arasında değişim göstermiş olup, en yüksek ortalama yumru ağırlıkları 148, 124 ve 142 numaralı klonlara aittir. 7. melez ailesindeki ortalama yumru ağırlığı 4,00 g ile 134,17 g arasında değişmiş olup, melez ailesinin ortalama yumru ağırlığı 37,37 gramdır. 7. melez ailesinde öne çıkan klon numaraları 451-14 ve 519 numaralı klonlardır. 8. melez ailesinde ortalama yumru ağırlığı 3,00-99,33 g arasında değişmiş olup, melez ailesinin ortalama yumru ağırlığı 28,05 gramdır. 8. melez ailesinde 476-416 ve 415 numaralı klonlardaki ortalama yumru ağırlıkları en yüksek ortalama yumru ağırlığıdır. 11. melez ailesinde ortalama yumru ağırlığı 31,94 g olarak belirlenmiş olup, ortalama yumru ağırlığı 5,83-120,00 g arasında değişim göstermiştir ve 535, 177 ve 187 numaralı klonlar ortalama yumru ağırlığı bakımından ön plana çıkmaktadır. 12. melez ailesinde ise ortalama yumru ağırlığı 30,27 g olarak belirlenmiştir, ortalama yumru ağırlıkları 4,33 g ile 82,25 g arasında değişim göstermiş olup 150-157 ve 156 numaralı klonlarda en yüksek ortalama yumru ağırlığı belirlenmiştir (Çizelge 4).

Çizelge 4. İncelenen melez ailelerine ait verim parametreleri
Table 4. Yield parameters of the hybrid families examined

MA	Bitki Başına Yumru Verimi (g/saksı)			Bitki Başına Yumru Sayısı (adet/bitki)			Ortalama Yumru Ağırlığı (g)		
	ORT	DS	ÖÇK	ORT	DS	ÖÇK	ORT	DS	ÖÇK
1	160,13	2,00-692,00	210/44/90	5,99	1-40	210/26/326	18,25	2,00-157,00	44/29/168
2	133,93	11,00-815,00	154/21/291	7,00	2-25	154/320/15	16,46	2,14-36,70	120/154/21
3	211,64	45,00-545,00	21/25/64	8,36	2-28	21/64/11	28,19	7,00-59,43	25/14/24
4	160,14	9,00-1084,00	26/18/132	6,77	1-29	28/26/150	22,44	6,25-72,00	110/17/26
5	215,40	6,00-820,00	75/115/202	7,13	1-27	175/146/115	26,11	6,00-57,60	148/124/142
6	223,10	7,00-1012,00	90/508/361	8,82	1-40	361/110/131	22,97	2,67-91,00	344/81/347
7	399,10	9,00-1747,00	509/38/479	11,51	1-40	462/115/106	37,37	4,00-134,17	451/14/519
8	332,12	12,00-1252,00	351/33/226	12,12	1-29	314/94/128	28,05	3,00-99,33	476/416/415
9	239,08	20,00-515,00	321/80/195	12,38	2-39	321/195/327	22,56	4,00-56,25	10/349/80
10	199,38	10,00-637,00	20/13/22	11,58	2-32	20/50/22	12,58	3,67-22,00	13/20/17
11	388,61	40,00-845,00	187/535/336	12,95	1-32	499/461/500	31,94	5,83-120,00	535/177/187
12	410,97	13,00-1078,00	174/156/705	15,03	3-33	189/21/42	30,27	4,33-82,25	150/157/156
ORT	267,24			9,97			24,77		

MA: Melez Ailesi; ORT : Ortalama; DS: Değişim Sınırları; ÖÇK: Öne Çıkan Klonlar

Patateste yumruların iriliği, çevresel etmenlerden kolayca etkilenebilen bir özelliktir (Hide, 1987). Patatesin genetik özelliği de yumru iriliği üzerinde etkili olup, patates ıslahında seleksiyon kriteri olarak kullanılmaktadır. Patateste yumru ağırlığı, kuru madde içeriği, azot kullanma kapasitesi, fotosentez etkinliği, solunum kayıplarının azlığı, toprağın yapısı ile ocak başına oluşan ana sap ve bu saplardaki yumru sayılarına da bağlıdır (Struik & Wiersema, 1999).

Ekolojik şartlardan kolayca etkilenen yumru iriliği, genotiplerin kalıtsal özellikleriyle de bağlantılıdır. Bu nedenle ıslah sürecinde yumru iriliği seçim kriteri olarak diğer özelliklerle birlikte değerlendirilmelidir (Struik & Wiersema, 1999). Pazarlama ve endüstriyel kullanımda yumru iriliği faktörü dikkate alınmaktadır. Bu özellik dekara yumru verimini de doğrudan etkileyen bir özellik olduğundan, seleksiyon çalışmalarında dikkate alınmakta ve ilerleyen generasyonlardaki sürdürülebilirliği izlenerek, ıslahçıların seçimlerinde etkili olmaktadır.

Sonuç

Patates ıslah programının bir parçası olan bu araştırmada, ele alınan melez aileleri ve klonlar bazı seleksiyon kriterleri bakımından incelendiğinde; Ana sap sayısı bakımından 7., 8., 9., 10., 11. ve 12 numaralı, bitki başına yumru verimi bakımından, 7., 8., 11. ve 12 numaralı, bitki başına yumru sayısı bakımından, 7., 8., 9., 10., 11. ve 12 numaralı, ortalama yumru ağırlığı bakımından, 3., 5., 7., 8., 11. ve 12 numaralı melez ailelerinin, melez aileleri genel ortalamalarının üzerinde değerlere sahip oldukları görülmüştür. Verim parametreleri toplu olarak incelendiğinde ise 7., 8., 11. ve 12 numaralı melez aileleri tüm parametrelerde ortak olarak iyi özellikler gösterdikleri belirlenmiştir. Elde edilen bulgular klonlar bazında incelendiğinde ise; 1. melez ailesinde 210 numaralı klon, 2. melez ailesinde 154 numaralı klon, 3. melez ailesinde 21- 25 ve 64 numaralı klonlar, 4. melez ailesinde 26 numaralı klon, 5. melez ailesinde 115 numaralı klon, 6. melez ailesinde 361 numaralı klon, 7. melez ailesinde 509-462 ve 451 numaralı klonlar, 8. melez ailesinde 351-314 ve 476 numaralı klonlar, 9. melez ailesinde 321-80 ve 195 numaralı klonlar, 10. melez ailesinde 20-13 ve 22 numaralı klonlar, 11. melez ailesinde 187 ve 535 numaralı klonlar, 12. melez ailesinde 156 numaralı klon ele alınan kriterler bakımından daha iyi performans göstermişlerdir. Burada oluşan varyasyon daha sonra belirlenen kriterlere göre seleksiyonlara tabi tutulacak generasyonlar ilerledikten sonra daha özel seleksiyonlara konu olduğunda tekerürrlü denemelere geçilecektir. Diğer taraftan öne çıkan klonların farklı lokasyonlardaki tepkileri ve özellikle kalite performansları ile değişen çevre koşullardaki stabilite durumları da değerlendirilerek, karar verilmesi önerilmiştir.

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Effects of Cyclic High Temperature Applied to Laying Hens with Different Body Weights During Molting on Second Laying Period Performance, Some Organ Weights and Leg Bone Characteristics

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ABSTRACT

This study aimed to evaluate the effects of different temperatures and body weights on the performance, egg quality, some organ weights and leg bone characteristics of laying hens in a non-fasting moulting treatment based on crushed barley consumption. In the study, 288 brown laying hens (Lohmann Brown-Classic) at the age of 80 weeks were used. Hens were divided into body weight (light, medium and heavy) and temperature (control and cyclic temperature) groups before moulting. During the moulting period, hens were kept at 21-22°C in the control group, and at 32°C from 10:00 to 18:00 h and from 21-22°C 10:00 to 18:00 h daily in the cyclic temperature group. The moulting program ensured that all hens in the groups lost 25% of their body weight in 35 days and there were no hen deaths during this period. The post-moulting performance of the hens was investigated in a curtain-sided poultry house under three months of spring and one month summer seasons. Cyclic high temperatures applied during the moulting period were not affected the performance of the production period, but improved the breaking strength, Haugh unit and albumen index of the eggs. In addition, in hens with high body weight, egg weight, tibia weight, length, width and breaking strength and weight and breaking strength of femur were increased in the post-moulting period. Egg production, egg weight, feed conversion ratio and egg quality characteristics improved significantly in the post-moult period compared to the pre-moult period. In moulted hens, while spleen weight increased, ovary, oviduct and liver weights decreased significantly It was found that cyclic high temperature applied during the moulting period positively affected some egg quality characteristics in the second production period.

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Farklı Canlı Ağırlığa Sahip Yumurtacı Tavuklara Tüy Dökümü Sırasında Uygulanan Döngüsel Yüksek Sıcaklığın İkinci Yumurtlama Dönemi Performansı, Bazı Organ Ağırlıkları ve Bacak Kemiği Özellikleri Üzerine Etkisi

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ÖZ

Bu çalışma, aç bırakılmadan kırılmış arpa tüketimine dayalı tüy dökümü uygulamasında, farklı sıcaklık ve canlı ağırlıkların yumurta tavuklarının performansı, yumurta kalitesi, bazı organ ağırlıkları ve bacak kemiği özellikleri üzerindeki etkilerini değerlendirmeyi amaçlamıştır. Çalışmada, zenginleştirilmiş kafeslerde yetiştirilen 80 haftalık yaşta 288 adet kahverengi yumurtacı tavuk (Lohmann Brown-Classic) kullanılmıştır. Tavuklar tüy dökümü öncesi canlı ağırlık (hafif, orta ve ağır) ve sıcaklık (kontrol ve döngüsel sıcaklık) gruplarına ayrılmıştır. Tüy dökümü döneminde, tavuklar kontrol grubunda 21-22°C'de, döngüsel sıcaklık grubunda ise günlük 10:00-18:00 saatleri arasında 32°C'de ve 18:00-10:00 saatleri arasında 21-22°C'de tutulmuştur. Tüy dökümü programı gruplardaki tavukların 35 günde canlı ağırlıklarının %25'ini kaybetmesini sağlamış ve bu dönemde tavuk ölümü olmamıştır. Tavukların tüy dökümü sonrası performansları perdeli bir kümeste üç ay bahar ve bir ay yaz mevsimi koşullarında incelenmiştir. Tüy dökümü periyodundaki döngüsel yüksek sıcaklık uygulaması, verim dönemi performansını etkilememiş, ancak yumurtaların kırılma direnci, Haugh birimi ve ak indeksini iyileştirmiştir. Ayrıca, canlı ağırlığı yüksek tavuklarda, tüy dökümü sonrası dönemde yumurta ağırlığı, tibia ağırlığı, uzunluğu, genişliği, kırılma direnci ile femurun ağırlığını ve kırılma direncini artmıştır. Yumurta verimi, yumurta ağırlığı, yemden yararlanma oranı ve yumurta kalite özellikleri tüy dökümü sonrası dönemde, tüy dökümü öncesine göre önemli ölçüde iyileşmiştir. Tüy dökümü döneminde tavuklarda, dalak ağırlığı artarken, yumurtalık, yumurta kanalı ve karaciğer ağırlıkları önemli ölçüde azalmıştır. Tüy dökümü döneminde uygulanan döngüsel yüksek sıcaklığın ikinci verim döneminde bazı yumurta kalite özelliklerini olumlu etkilediği ortaya çıkmıştır.

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Giriş

Kanatlıların tüyleri belirli dönemlerde dökülerek yenilemektedir. Tüy değiştirme olarak nitelendirilen bu fizyolojik süreç, üreme faaliyetlerine ara verilen bir dönemi başlatmaktadır. Kanatlıların, doğal tüy dökümü dışında, belirli programların uygulanması sonucunda tüylerini dökmeye zorlanmalarına ise zorlamalı tüy dökümü (ZTD) adı verilmektedir. Verim döneminin sonuna gelmiş yumurtacı sürülerde yumurtlama döngüsünü uzatmak, bozulan yumurta kalitesini iyileştirmek ve azalan yumurta verimini I.verim yılı seviyesinde olmasa da artırmak amacıyla uygulanan ZTD ekonomik açıdan yararlı bir uygulamadır (Akşit ve ark., 2003). Tavuklarda stres oluşturarak önemli oranda canlı ağırlık (CA) kaybını hedefleyen bu uygulama, üreme sisteminin morfolojik ve fizyolojik dinamiklerini değiştirerek, geçici bir süre yumurta üretimini durdurmakta, özellikle yumurtalığın ve yumurta kanalının dinlenmesini ve yenilenmesini sağlamaktadır (Akbari Moghaddam Kakhki ve ark., 2018; Berry, 2003; Butcher ve Miles, 2001; Cunningham ve Mauldin, 1996; Flock ve Anderson, 2016; Jeong ve ark., 2013; Webster, 2003). Ticari yumurtacılarda ilk verim dönemi, tavukların kondisyonuna ve ekonomik koşullara göre değişmekte olup, günümüzde kullanılan hibritlerin 100 haftalık performans verilerine rastlanmaktadır (Anonim, 2024a, b, c, d, e). Yumurta talebi ve fiyatı, ZTD uygulamasında belirleyici olmakla birlikte yumurtacı sürülerde programa genellikle 75-85 haftalık yaşlarda başlanmaktadır (Hu ve ark., 2019). ZTD programları, tavuklar üzerinde kısıtlamalarla stres oluşturan tek veya çok faktörlü uygulamalara dayanmakta ve çeşitlilik göstermektedir. ZTD amacı ile yem, su ve ışık sınırlaması, yemde kalsiyum veya sodyum gibi minerallerin kısıtlanmasına bağlı yetersiz besleme, alüminyum, çinko ve iyot gibi minerallerin yeme ilave edilmesi, dane tahıla dayalı yemleme, yonca unu kullanılması ve bazı ilaç ve hormon uygulanmaları kullanılan yöntemler arasında yer almaktadır (Aygün ve Olgun, 2010; Berry, 2003; Şenköylü, 2001; Webster, 2003; Yetişir ve Sarıca, 2004).

Açlık - susuzluk içeren ZTD programların hayvan refahı üzerine olan olumsuz etkileri bulunmaktadır. Avrupa Birliği'nin (AB) 95/98 nolu direktifi ile uzun süre karanlık uygulaması ve yem çekmeyi içeren ZTD programlarını yasaklanmıştır (Directive E.U., 1999). ABD'de ise 2006 yılından itibaren Yumurta Üreticileri Kooperatifi tarafından hayvancılık refah programları kapsamında kayıtlı yumurta çiftliklerinde yem - su kısıtlamasını içeren ZTD uygulamalarına izin verilmemektedir (Producers U.E., 2017). Bu yasaklamaların ardından hayvan refahını olumsuz etkilemeyecek, hayvanların önünden yemi veya suyu çekmeyi gerektirmeyen, hayvan refahını daha az olumsuz etkileyen ZTD yöntemleri geliştirilmiş ve başarıyla uygulanmıştır (Biggs ve ark., 2003). Bunlardan kırılmış arpa veya buğdayın kullanıldığı yöntemler iskelet sağlığını koruyan (Mazzuco ve Hester, 2005), ZTD sonrası yumurta verimini ve kalitesini artıran yöntemlerdir (Biggs ve ark., 2003, 2004).

Yumurtacı tavuklarda birinci verim yılı sonunda canlı ağırlık ve yumurta ağırlığı artar, kabuk kalitesinin bozulmasıyla kabuk kırılma direncini düşer. Diğer taraftan osteoporoza bağlı yapısal kemik kayıpları da artmaktadır (Gregory ve Wilkins, 1989; Kim ve ark., 2004; Whitehead, 2004). Bu kemik kaybı, iskeletin çeşitli bölgelerinde yüksek oranda kırığa neden olmakta ve kesilen yumurta tavuğu karkaslarında yaklaşık %34'lere varan yeni kırılmış kemikler saptandığı bildirilmektedir (Fleming, 1998; Gregory ve Wilkins, 1989; Whitehead ve Fleming, 2000). Yem çekmeye dayalı ZTD uygulamaları yaşlı yumurtacı tavuklarda kemik kaybını potansiyel olarak artıran bir faktördür (Park ve ark., 2004). ZTD programlarının temeli tek ya da çok sayıda stres faktörünün tavuklar üzerinde etkili olmasına dayanmaktadır. Yüksek çevre sıcaklıkları tavuklar üzerinde önemli bir stres kaynağıdır. Sıcak stresi tavuklarda verimi ve ürün kalitesini düşürmesinin yanı sıra ölümlere de yol açarak büyük ekonomik kayıplara neden olmaktadır (Akşit ve ark., 2006). Küresel ısınmaya bağlı olarak çevre sıcaklıklardaki artışların kanatlılar üzerindeki olumsuz etkileri özellikle yaz döneminde ortaya çıkmaktadır. Mevcut kaynakların daha uzun süre kullanımı küresel ısınmaya karşı alınabilecek önlemlerdendir. Yumurta tavuklarının uzun süre yumurtlatılması yarka ve yarka yetiştirme maliyetlerini azaltmaktadır (Traore ve Doyon, 2023). Hayvan refahı beklentileri ile örtüşen ZTD uygulamaları tavukçuluk sektörü tarafından küresel ısınmaya karşı alınabilecek önlemler arasında yer almaktadır. Yumurta tavuklarının verim döneminin uzatılması amacıyla uygulanan ZTD'de döngüsel yüksek sıcak uygulaması ile II. verim döneminde yüksek sıcaklıklarla karşılaştıklarında ortaya koyacakları performansın ve sıcaklık stresiyle mücadelelerindeki etkilerinin belirlenmesi ve verim dönemini tamamlamış tavuklarda ortaya çıkan canlı ağırlık farklılıklarına bağlı olarak II. verim dönemi etkilerinin saptanması önem arzetmektedir.

Bu çalışma, I. verim yılı sonunda (80 hafta) canlı ağırlık gruplarına ayrılan kahverengi yumurtacı tavuklara, açlık uygulanmadan kırılmış arpa verilerek, normal ve döngüsel yüksek sıcaklıkta zorlamalı tüy dökümü uygulamasının canlı ağırlıklar, yem tüketimi, yumurta verimi ve kalitesi, bazı iç organ ağırlıkları ve bacak kemiği özellikleri üzerine olan etkilerini belirlemeyi amaçlamıştır.

Materyal ve Yöntem

Araştırma Aydın Adnan Menderes Üniversitesi (ADÜ) Hayvan Deneyleri Yerel Etik Kurulunun 2020/086 sayılı izni ile ADÜ Ziraat Fakültesi Zootekni Bölümü Tavukçuluk Birimi ve ADÜ TARBİYOMER laboratuvarlarında yürütülmüştür.

Hayvan Materyali ve Deneme Düzeni

Çalışmada birinci verim yılını zenginleştirilmiş kafeslerde tamamlamış, 80 haftalık yaştaki Lohmann Brown-Classic kahverengi yumurtacı tavuklar kullanılmıştır. Araştırma her bir kafes gözünün 240 × 62,5 cm olduğu, 24 zenginleştirilmiş bölmeden oluşan, ısıtma ve soğutma düzenine sahip yumurta kümesinde yürütülmüştür. Her bölmede 12 tavuğun yer aldığı (2 sıcaklık × 3 ağırlık × 4 tekerrür) toplam 288 yumurtacı tavuk ile yürütülen çalışmada, hayvan başına 1250 cm^2 kullanılabilir kafes taban alanı sağlanmıştır.

Çalışmada kullanılan, birinci verim yılını tamamlamış 80 hafta yaşındaki sürüden sağlıklı ve normal davranış sergileyen yumurtacı tavuklar seçilerek ayak numarası takılmış ve bireysel tartımlarla başlangıç canlı ağırlıkları belirlendikten sonra düşük (1700-1950 g), orta (1951-2200 g) ve yüksek (2201-2450 g) olmak üzere 3 grup oluşturulmuştur. Araştırmanın ZTD döneminde yüksek sıcaklık uygulaması için kümes iki bölmeye ayrılmış, gereken ısı yalıtımı sağlanarak her iki bölmede (yüksek sıcak uygulaması hariç) benzer koşullar oluşturulmuştur. ZTD süresince yüksek sıcaklık, ilgili bölmedeki tavuklara 10:00 - 18:00 saatleri arasında 32°C, 18:00 - 10:00 saatleri arasında 21-22°C döngüsel sıcaklık olacak şekilde uygulanmıştır. Kontrol grubu ise ZTD programı süresince 21-22°C sıcaklıkta yetiştirilmiştir. Yüksek sıcaklık ve kontrol gruplarındaki sıcaklık koşulları elektronik kontrol sistemine bağlı soğutma sistemi (ped) ve konvektör ısıtıcılar ile sağlanmıştır. Deneme gruplarındaki sıcaklık değerleri wireless sıcaklık sensörleri ile izlenmiştir (TFA Dostmann–WheatherHub, Almanya). ZTD sonrası II. verim döneminde tüm deneme grupları eşit koşullarda çevre sıcaklığının etkisine maruz bırakılabilmesi için kümes, pencereli-perdeli sisteme dönüştürülmüş, kümes içi sıcaklığının 32°C'nin üzerine çıktığı dönemde soğutma sistemi devreye alınarak kümes içi sıcaklığın 32°C'yi geçmesi engellenmiştir. Çalışmadaki dönemler ile dönemlere ait sıcaklık ve oransal nem değeleri Çizelge 1'de sunulmuştur.

Aydınlatma programı ZTD programı bitişi sonrasında kademeli artışlar ile 16A-8K aydınlatma süresi şeklinde uygulanmıştır. Çalışmada tavuklara ZTD öncesi ve ZTD sonrası verim döneminde %16,0 ham protein, 2700 kcal/kg metabolik enerji, %4,0 kalsiyum, %0,5 yararlanılabilir fosfor, %0,42 metiyonin ve %0,85 lisin içeriğine sahip ticari yumurta yemi ve su *ad-libitum* olarak verilmiştir.

Zorlamalı Tüy Dökümü Programı

Çalışmada AB direktiflerine uygun (Directive, E.U., 1999), açlık - susuzluk içermeyen, tavuklara uzun süre karanlık ya da yem çekmenin uygulanmadığı, arpa tüketimine dayalı ZTD programı uygulanmıştır. Program süresince tavuklara 60 g/gün/tavuk kırılmış arpa verilmiş, su kısıtlanması yapılmamış ve aydınlatma süresi 10A-14K olarak uygulanmıştır. ZTD programı sürecinde tavukların sağlık durumları günlük olarak takip edilmiştir. ZTD programı, deneme gruplarında tekerrür (kafes) düzeyinde ortalama CA kaybı %25 oranına ulaşıncaya kadar sürdürülmüştür (Baker ve ark. 1983; Brake ve ark. 1982; Brake ve Mcdaniel 1981). Ağırlık kaybı %25'e ulaşan gruplarda arpa miktarı 100 g/tavuk/güne çıkartılmıştır. Deneme gruplarının tamamında CA kaybı %25'e ulaştığında yumurta yemine geçilmiştir.

Verim Özelliklerinin Belirlenmesi

Deneme gruplarında canlı ağırlıklar denemenin başlangıcında ve ZTD uygulamasının 30. gününde bireysel olarak belirlenmiş, hedeflenen %25 CA kaybına ulaşamayan gruplarda tartımlara günlük olarak devam edilerek %25 CA kaybına ulaştıkları gün kaydedilmiştir. Tavukların ZTD öncesi döneme ait yumurta verimi ve yemden yararlanma oranının hesaplanmasında, ZTD uygulama öncesi son 30 güne ait verilerden yararlanılmıştır. ZTD programı tamamlanıp yumurta yemine geçilmesinden sonra tekerrür düzeyinde tavukların yem tüketimi ve yumurta verimleri günlük olarak takip edilmiş, aylık dönemler şeklinde tavuk başına yem tüketimi belirlenmiştir. Gruplarda belirlenen tavuk ölümleri günlük olarak kaydedilmiş ve deneme sonu ölüm oranı hesaplanmıştır

$$\text{YYO} = \frac{\text{ATYA}}{\text{AYA}}$$

YYO : Yemden yararlanma oranı
ATYA: Aylık tüketilen yem ağırlığı
AYA : Aylık üretilen toplam yumurta ağırlığı

$$\text{YV} = \frac{\text{TYS}}{\text{TS}} \times 100$$

YV : Yumurta verimi (%)
TYS : Toplanan yumurta sayısı
TS : Tavuk sayısı

$$\text{ÖO} = \frac{\text{ÖTS}}{\text{BTS}} \times 100$$

ÖO : Ölüm oranı (%)
ÖTS : Ölen tavuk sayısı
BTS : Başlangıç tavuk sayısı

Yumurta Özelliklerinin Belirlenmesi

Yumurta iç ve dış kalite özelliklerinin incelenmesinde ZTD öncesi ve ZTD sonrası verim döneminin 30, 60, 90 ve 120. günlerinde toplanan yumurtaların tamamı kullanılmıştır. Yumurtalar 24 saat oda sıcaklığında bekletildikten sonra şekil indeksi (Şİ), Sarı indeksi (SAİ), Ak indeksi (Aİ), Haugh birimi (HB), Kabuk oranı (KO) belirlenmiştir. Haugh birimi yumurta ağırlığı (G) ve ak yüksekliğinden (h) yararlanılarak hesaplanmıştır (Haugh, 1937). Yumurta kabukları tartılmış, yumurta ağırlıklarına bölünerek kabuk oranı belirlenmiştir.

$$\text{Şİ} = \frac{\text{Yumurta genişliği}}{\text{Yumurta uzunluğu}} \times 100$$

$$\text{SAİ} = \frac{\text{Sarı yüksekliği}}{\text{Sarı çapı}} \times 100$$

$$\text{Aİ} = \frac{\text{Ak yüksekliği}}{(\text{Ak uzunluğu} + \text{Ak genişliği})/2} \times 100$$

$$\text{HB} = 100 \,\text{Log}\,(\text{h} + 7{,}57 - 1{,}7\,\text{G}^{0{,}37})$$

$$KO = \frac{\text{Kabuk ağırlığı}}{\text{Yumurta ağırlığı}} \times 100$$

Şİ : Şekil indeksi
SAİ : Sarı indeksi
Aİ : Ak indeksi
HB : Haugh birimi
KO : Kabuk oranı (%)

Yumurta kabuk kalınlığı, belirlenmesinde kabuğun sivri, orta ve küt kısımlarından mikrometre (Mitutoyo, Japonya) ölçülmüş, ile yapılan ölçümlerin ortalaması hesaplanmıştır. Yumurtanın kabuk kırılma direnci, Zwick/Roell-Z005 test cihazına (Zwick/Roell, Almanya) dikey olarak yerleştirilen yumurtanın çatladığı anda uygulanan kuvvet ile Newton (N) olarak belirlenmiştir.

Çizelge 1. Deneme süresinde kümes içi sıcaklık ve nem ortalamaları
Table 1. The average temperatures and humidity in poultry house during the experiment

Dönem	Sıcaklık[1] (°C)	Oransal nem (%)
Tüy dökümü öncesi (Aralık-Ocak)	20,2	58
Tüy dökümü dönemi (Ocak-Şubat)		
Kontrol	21-22	55
Döngüsel sıcaklık	32 / 21-22	42 / 55
Tüy dökümü sonrası		
1. ay (Mart)	20,6	53
2. ay (Nisan)	24,3	50
3. ay (Mayıs)	27,7	48
4. ay (Haziran)	32,3	41

[1]Tüy dökümü döneminde tavuklara kontrol grubunda 24 saat süresince 21-22°C sıcaklık, döngüsel sıcaklık grubunda 10:00-18:00 saatleri arasında 32°C ve 18:00-10:00 saatleri arasında 21-22°C sıcaklık uygulanmıştır.

İç organ ve Bacak Kemiği Özelliklerinin Belirlenmesi

İç organ ağırlıkları ve bacak kemiklerinin özelliklerinin belirlenmesi amacı ile ZTD öncesinde her CA grubundan 6 adet ve ZTD sonrası (II. yumurtlama döngüsünün başı) ise kontrol ve döngüsel sıcaklık gruplarındaki her bir CA grubundan 6'şar adet olmak üzere toplam 54 tavuk kesilmiştir. Örneklerin alındığı her iki dönemde de tavuklar Avrupa Gıda Güvenliği Otoritesi (EFSA, 2009) önerilerine uygun olarak su banyosunda elektrik akımı (AC-50 Hz akım, 100 mA/tavuk, 5 sn uygulama süresi) ile bilinçsizleştirildikten sonra kesilmiştir. Kesim sonrasında tavukların yumurtalık, yumurta kanalı, karaciğer ve dalak ağırlıkları belirlenmiştir. Tavukların sağ ve sol bacağı bütün olarak ayrılmış, +4°C'de numune torbalarında 24 saat bekletildikten sonra tibia ve femur kemikleri çıkarılmıştır. Sağ bacaktan elde edilen tibia ve femur kemikleri etlerinden ve yağlarından temizlendikten sonra etüvde (60°C, 24 saat) kurutularak ağırlıkları belirlenmiştir. Kemik ve iç organlar 0,01g hassasiyetindeki terazi ile tartılmıştır. Kemiklerin uzunluk ve çapları ise dijital kumpas kullanılarak belirlenmiştir (Mitutoyo Absolute Digimatic, Japonya). Kemiklerin kırılma direnci, Warner - Bratzer yöntemiyle Zwick/Roell Z 005 test cihazında (Zwick/Roell, Almanya) Newton (N) olarak tespit edilmiştir.

Sol bacaktan elde edilen etleri uzaklaştırılmış tibia ve femur kemikleri 10 dakika sıcak suda bekletildikten sonra yumuşak dokuları uzaklaştırılmış ve oda sıcaklığında üç gün bekletilerek kurutulmuştur. Kurutulmuş kemik örnekleri öğütülmüş, tartılarak ağırlığı belirlenen örnekler porselen krozelere konarak kül fırınında 600°C de 24 saat yakılmıştır. Yakma işlemi sonrasında elde edilen kül miktarı tartılarak, kül oranı belirlenmiştir (kül oranı (%) = (kül ağırlığı / yakma öncesi ağırlık) ×100).

İstatistiki Yöntem

Çalışmada deneme gruplarından elde edilen veriler SPSS 18,0 (PASW Inc., Chicago. IL. USA) istatistik paket programının Genel Doğrusal Modelleri arasında yer alan Çok Değişkenli Analiz yöntemi kullanılarak analiz edilmiştir. Modelde sıcaklık (S), canlı ağırlık (CA) ve verim dönemi (VD) ile bu etkiler arasındaki ikili (S × CA, CA × VD ve S × VD) ve üçlü (S × CA ×VD) interaksiyonlar sabit etki, bölme etkisi de rastgele etki olarak tanımlanmıştır. Ortalamalar arasındaki farkların önemi (P<0,05) Tukey HSD testinden yararlanılarak hesaplanmıştır.

Bulgular ve Tartışma

Zorlamalı tüy dökümünün uygulandığı dönemde deneme gruplarında herhangi bir nedenle deneme dışı bırakılan ya da ölen tavuk olmamıştır. ZTD döneminde toplam ölüm oranının %1,25'i geçememesi gerektiği öngörülmektedir (Bell ve Kuney, 1992). Denemede tavukları aç bırakmadan günlük 60 g/tavuk kırılmış arpa verilerek uygulanan ZTD programının ölümlere yol açmadan başarılı bir şekilde sonuçlanması hayvan refahı bakımından olumlu bir gelişme olarak değerlendirilmiştir. ZTD sonrası verim döneminde tavuklarda ölüm oranı ZTD'de döngüsel sıcak uygulanan grupta %1,4 ve kontrolde ise %2,1 olmuştur.

İlk verim döneminin sonuna gelmiş yumurta tavuklarının tüy dökümü öncesi canlı ağırlıkları, ZTD'ne maruz bırakıldıklarında sıcaklığın ve canlı ağırlık farklılıklarının CA değişimi üzerindeki etkileri Çizelge 2'de verilmiştir. Yumurta tavuklarının I. verim dönemi sonu (80 hafta) canlı ağırlıklarına göre tüy dökümü öncesi oluşturulan ağırlık grupları arasındaki CA farkları önemli bulunmuş, bu farklar tüy dökümünün 30. gününde de devam ettiği görülmüştür (P<0,05). Bununla birlikte, ZTD'de uygulanan sıcaklığın ZTD'nin 30. gününde meydana gelen CA kayıbını (%) ve %25 CA kaybına ulaşma yaşını etkilemediği ortaya çıkmıştır (P>0,05). Bulgularımızdan farklı olarak Akşit ve ark. (2003) açlık uyguladıkları, Ocak ve ark. (2004) Zn ilaveli yem verdikleri ZTD programlarında başlangıç CA düşük olan yumurta tavuklarının daha fazla CA kaybettiklerini bildirmişlerdir. Canlı ağırlık kayıplarındaki farkın tüy dökümü programlarındaki uygulama farklılıklarından kaynaklanmış olabileceği düşünülmektedir. Deneme grupları en erken 33,6'cı günde, en geç 35. günde başlangıç canlı ağırlığının %25'ni kaybetmiştir (Çizelge 2). Andrews ve ark. (1987) tavuklarda, Kashmiri ve Vatsalya (2011) Japon bıldırcında tüy dökümü sırasında meydana gelen CA kaybının %25'inin doğrudan karaciğer, yumurtalık ve yumurta kanalındaki kayıplara bağlı olduğunu bildirmişlerdir. Denemede açlık uygulanmadan günde 60 g/tavuk kırılmış arpa verilerek uygulanan zorlamalı tüy dökümü programının tüm deneme gruplarında benzer bir sürede, üstelik herhangi bir tavuk ölümüne yol açmadan %25 CA kaybı hedefine ulaşılmasını sağlaması oldukça önemli bir sonuç olarak değerlendirilmiştir. Açlık uygulanan ZTD çalışmalarında %25 CA kaybına Andreatti ve ark. (2019) açlık döneminin 10., Akşit ve ark. (2003) 12. günlerinde ulaşılmıştır.

Çizelge 2. Tüy dökümü dönemi sıcaklığı ve canlı ağırlığın yumurta tavuklarının canlı ağırlık değişimi üzerine etkisi [1]
Table 2. Effects of molting period temperature and body weight on body weights of laying hens

Uygulamalar	Canlı ağırlık (g)		Canlı ağırlık kaybı	
	Tüy dökümü öncesi	Tüy dökümünün 30. günü	Tüy dökümünün 30. günü CA kaybı (%)	% 25 CA kaybına ulaşma yaşı (gün)
Sıcaklık[2]				
Kontrol	2024	1580	21,8	34,3
Döngüsel sıcaklık	2021	1569	22,1	34,5
SEM[3]	7,205	12,558	0,765	1,128
Canlı ağırlık				
Hafif	1813[c]	1429[c]	21,1	35,0
Orta	2001[b]	1566[b]	21,7	34,6
Ağır	2254[a]	1728[a]	23,0	33,6
SEM[3]	8,847	15,380	0,829	1,369
	Önemlilik (P)			
Sıcaklık (S)	-	0,540	0,748	0,917
Canlı Ağırlık (CA)	<0,001	<0,001	0,259	0,767
S × CA	-	0,391	0,297	0,779

[1]a-c: Aynı sütunda farklı harfleri taşıyan özellikler arasındaki farklar önemlidir (P<0,05); [2]Tüy dökümü döneminde tavuklara kontrol grubunda 24 saat süresince 21-22°C sıcaklık, döngüsel sıcaklık grubunda 10:00-18:00 saatleri arasında 32°C ve 18:00-10:00 saatleri arasında 21-22°C sıcaklık uygulanmıştır; [3] SEM: Ortalamaların Standart Hatası

Onbaşılar ve ark. (2020) yumurta tavuklarına tüy dökümü için *ad libitum* olarak verdikleri dane arpa ile %20 CA kaybına 27. gün ulaşmışlardır. Açlık uygulanan tüy dökümü programlarının yaşlı sürülerde aşırı CA kayıplarına yol açtığı, çok yüksek ölüm oranlarına neden olduğu bildirilmektedir (Rafeeq ve ark., 2013). ZTD döneminde tavukların canlı ağırlık kayıpları %15-40 arasında değişmektedir (Baker ve ark., 1983; Hazan ve Yalçın, 1988; Zimmermann ve ark., 1987). Yumurta tavuklarının ZTD sonrası II. yumurtlama döngüsünde iyi bir performansa sahip olması ZTD döneminde CA kaybının %25-35 arasında olmasına bağlı olduğu ileri sürülmekte (Baker ve ark. 1983; Brake ve ark. 1982; Brake ve Mcdaniel 1981), ZTD sırasında %35'i geçen ağırlık kayıplarının ise tavukların sağlığını ve sonraki verimlerini olumsuz etkileyebileceği bildirmektedir (Berry, 2003).

ZTD döneminde uygulanan sıcaklığın yumurta verimi, yumurta ağırlığı, yem tüketimi ve yemden yararlanma oranı üzerinde önemli bir etkisinin bulunmadığı belirlenmiştir (Çizelge 3). Tavukların tüy dökümü öncesi canlı ağırlıklarının ise sadece yumurta ağırlıklarını etkilediği (P<0,05), en ağır yumurtaları (68,79 g) yüksek canlı ağırlık grubundaki tavukların ürettiği (P<0,05), hafif ve ağır tavukların yumurta ağırlıkları arasındaki farkın önemli olduğu, canlı ağırlıkları yüksek tavukların yumurta ağırlıklarının da yüksek olduğu görülmüştür (P<0,05). ZTD öncesi (76-80 hafta) dönemde tavukların %68,43 olan yumurta verimi, ZTD'den sonra 1.ayda %56,77, 2. ayda %82,88 ve 3. ayda %81,58 olurken sıcakların etkili olduğu 4. ayda (Haziran) ise yumurta verimi %69,89 ile tüy dökümü öncesi verim düzeyine kadar düştüğü belirlenmiştir (P<0,05). Verim döneminin yumurta ağırlığı üzerindeki etkisi önemli bulunmuş (P<0,05) en düşük yumurta ağırlığı 4. ayda (63,30 g), en yüksek yumurta ağırlığının ise 3. ayda (69,41 g), ZTD öncesi dönemde ve 1. aydaki yumurtaların ise benzer ağırlıklarda olduğu tespit edilmiştir (P<0,05). Tavukların yem tüketimi uygulamalarından etkilenmemiştir (P>0,05). Verim döneminin yemden yararlanma oranı üzerindeki etkisi önemli bulunmuştur (P<0,05). Yemden yararlanma oranı ZTD sonrası 1. ayda 3,01 g/g ile en kötü, 2. ve 3. aylarda sırasıyla 2,07 g/g ve 2,08 g/g ile en iyi yemden yararlanma oranına sahip olduğu (P<0,05) ve 1. aya ait kötü sonucun 65,76 g düşük yumurta ağırlığı ve düşük (%56,77) yumurta veriminin de bundan kaynaklandığı düşünülmektedir (P<0,05). Onbaşılar ve ark. (2020) 75 haftalık kahverengi yumurtacı tavuklara 27 gün *ad-libitum* dane arpa ve 28-35 gün, 60-80 g/gün/tavuk karma yem verdikleri ZTD uygulamasında bulgularımıza benzer olarak ZTD sonrası verim döneminin 1. ayında yumurta veriminin ZTD öncesi dönemden daha düşük olduğunu, 2. aydan itibaren yumurta veriminin arttığını ve ZTD öncesi dönemden daha yüksek olduğunu bildirmişlerdir. Aynı çalışmada bulgularımıza benzer şekilde ZTD öncesi dönemle benzer olan 1. aya ait yumurta ağırlığı ilerleyen verim döneminde artmıştır (P<0,05). ZTD sonrası verim döneminin 1. ayında yumurta veriminin düşük olması, bu dönemde yemden yararlanma oranın da en kötü değere sahip olmasından kaynaklanmıştır. Verim döneminin diğer aylarında yemden yararlanma oranları arasındaki farklar önemli değildir (P>0,05). Araştırmamızda Onbaşılar ve ark. (2020) tarafından yürütülen çalışmadan farklı olarak tavukların yaz dönemindeki Haziran ayı (4.ay) performansları da incelenmiştir. Bulgularımıza göre Haziran ayı kümes içi sıcaklığına bağlı tavukların yem tüketimlerinde önemli bulunmayan bir azalma görülmüştür (P>0,05). Ancak, 4.ayda tavukların maruz kaldığı sıcakların yumurta verimi ve ağırlığında önemli azalmalara neden olduğu görülmüştür. Sıcak stresi yumurtacı tavukların yem tüketimini, canlı ağırlığını, yumurta üretimini, üreme özelliklerini ve yaşama gücünü azaltmaktadır (Mashaly ve ark., 2004). Akşit ve ark. (2003) tarafından kahverengi yumurtacı tavuklar üzerinde yürütülen, 12 günlük yemsiz dönemi içeren ve ağırlık gruplarının yer aldığı (hafif, orta ve ağır) ZTD çalışmasında, ZTD sonrası verim döneminde yumurta ağırlığının tavukların CA farkından etkilenmediğini, ancak tavuk ağırlığı ile ZTD sonrası yumurta verimi arasında önemli düzeyde ters bir ilişkinin olduğu bildirilmektedir. Ocak ve ark (2004) farklı CA gruplarına ayrılmış kahverengi yumurtacı tavuklarda yüksek miktarda çinko içeren (15.000 ppm) yemlerle uyguladıkları ZTD'nün tavukların canlı ağırlıklarının yumurta verimlerini etkilemediğini bildirmiştir.

Çizelge 3. Tüy dökümü dönemi sıcaklığı, canlı ağırlık ve verim döneminin yumurta tavuklarının yumurta verimi, yumurta ağırlığı, yem tüketimi ve yemden yararlanma oranı üzerine etkisi[1]

Table 3. Effects of molting period temperature, body weight and laying period on egg production, egg weight, feed intake and feed conversion ratio of laying hens

Uygulamalar	Özellikler			
	Yumurta verimi (%)	Yumurta ağırlığı (g)	Yem tüketimi (g)	Yemden yararlanma oranı (g/g)
Sıcaklık[2]				
Kontrol	70,20	66,71	115,89	2,47
Döngüsel sıcaklık	73,63	66,46	112,98	2,31
SEM[3]	1,500	0,595	1,656	0,040
Canlı ağırlık				
Hafif	72,60	64,29^{b}	111,04	2,38
Orta	74,34	66,68^{ab}	115,98	2,34
Ağır	68,80	68,79^{a}	116,31	2,46
SEM[3]	1,837	0,729	2,028	0,049
Verim dönemi				
Tüy dökümü öncesi (Aralık - Ocak)	68,43^{b}	66,29^{b}	115,35	2,54^{ab}
Tüy dökümü sonrası				
1. ay (Mart)	56,77^{c}	65,60^{b}	115,42	3,10^{a}
2. ay (Nisan)	82,88^{a}	68,36^{ab}	117,37	2,07^{b}
3. ay (Mayıs)	81,58^{a}	69,41^{a}	117,93	2,08^{b}
4. ay (Haziran)	69,89^{b}	63,30^{c}	106,21	2,40^{ab}
SEM[3]	1,837	0,554	2,028	0,062
	Önemlilik (P)			
Sıcaklık (S)	0,111	0,322	0,227	0,081
Canlı Ağırlık (CA)	0,102	<0,001	0,119	0,539
Verim Dönemi (VD)	<0,001	0,041	0,577	<0,001
S × CA	0,552	0,178	0,734	0,130
S × VD	0,080	0,086	0,775	0,125
CA × VD	0,872	0,943	0,991	0,921
S × CA × VD	0,848	0,788	0,737	0,162

[1]a-c: Aynı sütunda farklı harfleri taşıyan özellikler arasındaki farklar önemlidir (P<0,05); [2]Tüy dökümü döneminde tavuklara kontrol grubunda 24 saat süresince 21-22°C sıcaklık, döngüsel sıcaklık grubunda 10:00-18:00 saatleri arasında 32°C ve 18:00-10:00 saatleri arasında 21-22°C sıcaklık uygulanmıştır; [3]SEM: Ortalamaların Standart Hatası.

Araştırmada ZTD döneminde uygulanan döngüsel yüksek sıcaklığın, yumurtaların kırılma direnci, Haugh birimi ve ak indeksi değerlerini önemli ölçüde yükselttiği (P<0,05) ve diğer yumurta kalite özelliklerini etkilemediği belirlenmiştir (Çizelge 4). Kanatlı hayvanların yetiştirme dönemlerinde maruz kaldıkları yüksek çevre sıcaklıkları yaşama gücü, kanatlıların refahı ve verimleri üzerinde olumsuz etkilere sahiptir (Akşit ve ark., 2006). Ancak, bu çalışmada ZTD döneminde uygulanan yüksek sıcaklığın yetiştirme döneminden farklı olarak her hangi bir özellik üzerinde olumsuz etki oluşturmamış, kabuk kırılma direnci, Haugh birimi ve ak indeksini yükseltmiştir. Meydana gelen bu etkinin ZTD sürecinde tüylerini kaybeden tavukların, düşük yem tüketimi ve yağ birikiminin azalmasına (Alodan ve Mashaly, 1999) bağlı olarak vücut sıcaklılarını yeterince dengeleyemedikleri ve buna bağlı olarak fizyolojik dinlenme ve üreme sisteminin onarılma sürecinde kontrol grubundaki tavukların sıcaklık grubundakilere göre daha düşük sıcaklıklarda geçirmeleri yumurtalık ve yumurta kanalının onarım sürecini uzatmış olmasına dayandırılabilir. Dolayısıyla ZTD dönemindeki yüksek kümes içi sıcaklığı sıcak grubundaki tavuklara bir avantaj sağlamış olabileceği düşünülmektedir. Bulgularımıza göre canlı ağırlık gruplarının yumurta kalite özellikleri üzerindeki etkisinin önemli olmadığı (P>0,05), buna karşın verim dönemindeki yumurtaların incelenen tüm özellikleri üzerinde oldukça önemli bir etkiye sahip olduğu belirlenmiştir (P<0,05). Yumurta kabuğunun kalınlığı, ağırlığı ve oranının, ZTD öncesinde ve verim döneminin 4. ayında diğer aylara göre daha düşük bulunmuş, 2. ve 3. aylarda ise kabuk özelliklerinin iyileştiği ve dönemler arasındaki farkın önemli olduğu belirlenmiştir (P<0,05).

Çalışma bulgularına göre ZTD sonrasındaki 1, 2 ve 3. aylarda elde edilen yumurtaların diğer dönemlere göre önemli düzeyde daha yüksek kabuk oranına ve kırılma direncine sahip olmuşlardır (P<0,05). ZTD öncesinde yumurtaların kabuk oranının en düşük, 4.ay döneminde ise ZTD öncesine göre daha yüksek, fakat 1., 2. ve 3. aylara göre daha düşük olduğu belirlenmiştir (P<0,05). 4. ayda elde edilen yumurtaların kırılma direncinin en düşük, ZTD öncesi grubun ise 4. aya göre daha iyi olduğu belirlenmiştir (P<0,05). ZTD uygulamaları tavukların bir dönem daha üretimde kullanılmalarına imkan verirken, yarattığı olumlu etkilerden biri de yumurta kabuk kalitesinin iyileşmesidir (Alodan ve Mashaly 1999; Barker ve ark., 1983; Silva-Mendoça ve ark., 2015). Araştırmada incelenen yumurta kabuk kalınlığı, ağırlığı, oranı ve kırılma direncinin ZTD öncesi dönemde düşük olduğu, önceki çalışmalarda olduğu gibi ZTD sonrasında kabuk özelliklerinin iyileştiği, ancak yaz döneminde Haziran ayındaki sıcaklık stresinin yumurta özelliklerini ZTD öncesi değerlere yakın bir düzeye taşıdığı belirlenmiştir.

Çizelge 4. Tüy dökümü dönemi sıcaklığı, canlı ağırlık ve verim döneminin yumurta kalite özellikleri üzerine etkisi [1]
Table 4. Effects of moulting period temperature, body weight and laying period on egg quality traits of laying hens

Uygulamalar	Özellikler							
	Kabuk Kalınlığı (mm)	Kabuk ağırlığı (g)	Kabuk oranı (%)	Kırılma direnci (N)	Şekil indeksi (%)	Haugh birimi	Sarı indeksi (%)	Ak indeksi (%)
Sıcaklık[2]								
Kontrol	0,399	6,72	10,07	39,39^{b}	76,81	82,16^{b}	45,72	8,66^{b}
Döngüsel sıcaklık	0,400	6,79	10,11	41,48^{a}	77,02	83,03^{a}	45,78	8,88^{a}
SEM[3]	0,002	0,310	0,057	0,550	0,146	0,266	0,148	0,065
Canlı ağırlık								
Hafif	0,401	6,67	10,08	39,61	76,90	83,11	45,90	8,93
Orta	0,397	6,75	10,09	40,15	76,90	82,70	45,90	8,74
Ağır	0,399	6,85	10,10	41,54	76,95	81,97	45,45	8,68
SEM[3]	0,002	0,037	0,070	0,673	0,179	0,326	0,182	0,080
	Verim dönemi							
Tüy dökümü öncesi (Aralık- Ocak)	0,374^{c}	6,13^{c}	9,09^{c}	36,66^{b}	75,05^{b}	84,58^{a}	46,09^{bc}	9,15^{b}
Tüy dökümü sonrası								
1. ay (Mart)	0,401^{b}	7,10^{b}	10,61^{a}	44,84^{a}	77,48^{a}	84,19^{ab}	47,77^{a}	9,73^{a}
2. ay (Nisan)	0,413^{a}	7,20^{a}	10,59^{a}	43,70^{a}	77,68^{a}	82,87^{b}	45,92^{c}	8,66^{c}
3. ay (Mayıs)	0,416^{a}	7,28^{a}	10,62^{a}	44,22^{a}	76,72^{ab}	83,15^{ab}	46,92^{b}	8,58^{c}
4. ay (Haziran)	0,391^{c}	6,10^{c}	9,54^{b}	32,76^{c}	76,63^{ab}	78,20^{c}	42,06^{d}	7,61^{d}
SEM[3]	0,002	0,043	0,080	0,774	0,205	0,374	0,208	0,92
	Önemlilik (P)							
Sıcaklık (S)	0,607	0,167	0,812	0,007	0,339	0,020	0,780	0,037
Canlı Ağırlık (CA)	0,476	0,322	0,767	0,112	0,966	0,054	0,128	0,064
Verim Dönemi (VD)	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
S × CA	0,220	0,297	0,521	0,289	0,867	0,404	0,719	0,322
S × VD	0,515	0,110	0,282	0,500	0,490	0,352	0,135	0,224
A × VD	0,205	0,479	0,459	0,554	0,524	0,114	0,257	0,179
S × CA × VD	0,089	0,213	0,282	0,438	0,490	0,360	0,306	0,425

[1]a-c: Aynı sütunda farklı harfleri taşıyan özellikler arasındaki farklar önemlidir (P<0,05); [2]Tüy dökümü döneminde tavuklara kontrol grubunda 24 saat süresince 21-22°C sıcaklık; döngüsel sıcaklık grubunda 10:00-18:00 saatleri arasında 32°C ve 18:00-10:00 saatleri arasında 21-22°C sıcaklık uygulanmıştır; [3] SEM: Ortalamaların Standart Hatası.

Bu sonuçlar Kim ve ark. (2024) tarafından bildirilen sıcağın yumurta tavukları üzerinde meydana getirdiği etkilerin ZTD sonrası dönemde de benzer şekilde ortaya çıktığını, sıcaklık stresinin tavukların performansı üzerindeki olumsuz ve sert etkilerini ortaya koyduğu yönündeki bulgularını desteklemektedir. Tavuk yumurtalarında şekil indeksi tavuk yaşı, genotip, sağlık ve yetiştirme sistemleri gibi faktörelere bağlı olarak değişmekle birlikte, genellikle %72 - 76 aralığındaki değerler normal oval şekil olarak kabul edilmektedir (Duman ve ark., 2016). Şekil indeksi <%72 olan yumurtaların sivri, >%76 olanların ise yuvarlak şekli daha belirgindir. Yumurta tavuklarında ilerleyen yaşla birlikte artan yumurta ağırlığı yumurta üniformitesinin bozulmasına neden olarak şekil indeksini olumsuz etkilemekte, ZTD sonrası 2. verim döneminde ise yumurta şekil indeksi iyileşmektedir (Küçükyılmaz ve ark., 2003). Bulgularımız ZTD öncesi döneme göre 1. ve 2. aylarda şekil indeksinin arttığı (P<0,05), ilerleyen verim dönemi ile birlikte ZTD öncesi dönemle aradaki farkın önemsiz olduğu anlaşılmaktadır (P>0,05). ZTD sonrasında yumurta şekil indeksinin bir miktar artışla %76,63 ile 77,68 aralığında gerçekleştiği, ZTD öncesi döneme göre 1. ve 2. aylarda daha yuvarlak yumurtalar elde edildiği belirlenmiştir. Bununla birlikte tane arpa kullanılarak gerçekleştirilen ZTD uygulamasının verim döneminde bozulan şekil indeksini iyileştirme yönünde etkilerinin olduğu bildirilmektedir (Petek ve ark., 2008). Yumurta iç kalite özelliklerinden olan Haugh birimi, sarı ve ak indeksleri yumurtanın iç kalitesinin tanımlanmasında kullanılmaktadır. Haugh birimi, ak yüksekliği ve yumurta ağırlığının logaritmik fonksiyonuna dayanan objektif bir yumurta kalitesi ölçüsüdür. Yumurtanın depolama süresi ve sıcaklığı, tavuk yaşı, genotip, beslenme, hastalık, ZTD ve ilaç tedavisi Haugh birimini etkilemektedir (Roberts, 2004). ZTD sonrasında üreme organlarının iyileşmesine bağlı olarak albümin kalitesinin iyileştiğini ve bu durumun Haugh birimini olumlu etkilediğini bildirilmektedir (Attia ve ark., 1992; Tona ve ark., 2002). Bulgularımıza göre ZTD öncesi ve 1. ayda ak indeksinin yüksek olduğu belilrlenmiş, 2. ve 3. aylardaki yüksek yumurta ağırlığı Haugh birimi üzerinde olumlu etki yaratmıştır. Bu etkiye bağlı olarak en yüksek Haugh birimi ZTD öncesi dönemde, 2. ayda orta düzeyde ve düşen yumurta ağırlığı ve en düşük ak indeksi nedeni ile sıcak dönem olan 4.ayda saptanmıştır (P<0,05). Bulgularımızda ZTD sonrası II. verim döneminde ak ve sarı indekslerinin 1. ayda en yüksek değere sahip olduğu ilerleyen yaşla birlikte ak ve sarı indeks değerlerinin azaldığı, 4.ayda ise ZTD öncesi döneme ait indeks değerinden daha düşük düzeye düştüğü belirlenmiştir. ZTD sonrası verim döneminde dinlenmiş ve yenilenmiş üreme organlarının 1. ayda ak ve sarı indeklerini olumlu etkilediği fakat bu durumun uzun sürmediği anlaşılmaktadır.

Çizelge 5. Tüy dökümü dönemi sıcaklığı, canlı ağırlık ve tüy dökümü döneminin yumurta tavuklarının bazı organ ağırlıkları üzerine etkisi [1]

Table 5. Effects of molting period temperature, body weight and molting period on some organ weights of laying hens

Uygulamalar	Organlar ağırlıkları (g)			
	Yumurtalık	Yumurta kanalı	Karaciğer	Dalak
Sıcaklık[2]				
Kontrol	29,49	31,88	26,84	1,85
Döngüsel sıcaklık	31,08	39,05	28,14	1,59
SEM[3]	2,482	3,253	0,992	0,113
Canlı ağırlık				
Hafif	30,97	33,00	27,06	1,68
Orta	30,01	35,39	27,76	1,65
Ağır	29,87	38,00	27,65	1,82
SEM[3]	3,039	3,984	1,215	0,139
Tüy dökümü dönemi				
Başlangıç	55,08[a]	61,19[a]	29,15[a]	1,494[b]
Bitiş	5,48[b]	9,73[b]	25,83[b]	1,940[a]
SEM[3]	2,462	3,257	0,984	1,125
	Önemlilik (P)			
Sıcaklık (S)	0,654	0,128	0,361	0,119
Canlı Ağırlık (CA)	0,962	0,677	0,909	0,676
Tüy Dökümü dönemi (TD)	<0,001	<0,001	0,023	0,009
S × CA	0,620	0,563	0,977	0,754
S × TD	0,353	0,774	0,976	0,369
A × TD	0,437	0,442	0,965	0,256
S × CA × TD	0,620	0,995	0,156	0,598

[1]a-b: Aynı sütunda farklı harfleri taşıyan özellikler arasındaki farklar önemlidir (P<0,05); [2]Tüy dökümü döneminde tavuklara kontrol grubunda 24 saat süresince 21-22°C sıcaklık; döngüsel sıcaklık grubunda 10:00-18:00 saatleri arasında 32°C ve 18:00-10:00 saatleri arasında 21-22°C sıcaklık uygulanmıştır; [3]SEM: Ortalamaların Standart Hatası.

Tüy dökümü dönemi sıcaklığı, canlı ağırlık ve tüy dökümü döneminin yumurtacı tavukların yumurtalık, yumurta kanalı, karaciğer ve dalak ağırlıkları üzerine olan etkileri Çizelge 5'de verilmiştir. ZTD döneminde uygulanan sıcaklığın ve tavukların canlı ağırlıklarının yumurtalık, yumurta kanalı, karaciğer ve dalak ağırlıkları üzerindeki etkisi önemsizdir (P>0,05). Tüy dökümü döneminin tavukların yumurtalık, yumurta kanalı, dalak ve karaciğer ağırlıkları üzerinde önemli bir etkiye sahip olduğu (P<0,05), tüy dökümü döneminde tavukların yumurtalık, yumurta kanalı ve karaciğer ağırlıklarının tüy dökümü öncesi döneme göre önemli düzeyde azaldığı, dalak ağırlığının ise arttığı belirlenmiştir (P<0,05). ZTD sırasında, kanatlılarda üreme sistemi tamamen yeniden şekillenerek gerileme ve yenilenme sürecine girebilmektedir (Sundaresan ve ark., 2007). Bu süreçte yumurtalık ve yumurta kanalı küçülmektedir. Bulgularımızla uyumlu benzer çalışmalarda ZTD döneminde yumurtalık, yumurta kanalı ve karaciğer ağırlıklarının önemli düzeyde azaldığı bildirmektedir (Akşit ve ark., 2003; Brake ve ark., 1979; Dastar ve ark., 2016). ZTD'nü başlatmak için uygulanan açlık, T-lenfosit alt popülasyonlarını (Holt, 1992) ve plazma kortikosteron seviyelerini (Davis ve ark., 2000) değiştirmiş ve ZTD uygulanan tavuklarda hematokrit, eozinofil ve lökosit sayılarında artış olmuştur (Brake ve ark., 1982). Araştırma bulgularımıza göre bağışıklık sisteminin önemli organlarından olan dalak ağırlığı ZTD dönemi sonunda önemli düzeyde artmıştır (P<0,05).

Tüy dökümü dönemi sıcaklığı, canlı ağırlık ve tüy dökümü döneminin yumurta tavuklarının bacak kemiği özellikleri üzerine olan etkisi Çizelge 6'de sunulmuştur. ZTD döneminde uygulanan sıcaklığın tavukların tibia ve femur kemik özellikleri üzerindeki etkisi önemsiz bulunmuştur (P>0,05). Tavukların canlı ağırlığının bazı tibia ve femur kemik özelliklerini etkileyerek hafif ağırlık grubundaki tavukların tibia ve femur ağırlığı ile tibia kemiğinin uzunluğunun diğer ağırlık gruplarından önemli düzeyde düşük olduğu (P<0,05) ve tibia kemiği çapı ile her iki kemiğin kırılma dirençleri bakımından hafif ve ağır gruplar arasındaki farkın önemli olduğu belirlenmiştir (P<0,05). Bulgularımız düşük CA sahip tavukların hafif, kısa ince ve kırılma direnci düşük kemiklere sahip olduğunu, ağır tavuklarda ise bacak kemiği özelliklerinin hafif tavuklara göre daha iyi özelliklere sahip olduğunu ortaya koymaktadır. Tavuklarda yüksek yumurta verimi kalsiyum metabolizmasındaki dengesizlikler yumurta tavuklarının kemik yapısını olumsuz etkileyebilmektedir (Helva ve ark., 2024). Yüksek yumurta verimi ve ilerleyen yaşla birlikte verim dönemi sonuna doğru yumurta kabuğu özellikleri kötüleşmekte ve kemik yapısı zayıflamaktadır. Kanatlılarda kemikler yumurta kabuğunun oluşumu sırasında gereken kalsiyum için önemli kaynaklardandır (Scanes, 2021). Kanatlılara özgü medullar kemikler negatif kalsiyum dengesini önlemek için verim döneminden önce şekillenen kemiklerdir (Hester, 2017). Bulgularımıza göre tüy dökümü dönemindeki önemli değişimin medullar kemik özelliklerinde olan tibia kemiğinin çap, kırılma direnci ve kül miktarı üzerinde meydana geldiği (P<0,05), femur kemiği özelliklerinin ZTD'den etkilenmediği anlaşılmaktadır (P>0,05). ZTD öncesinde daha ince çap, daha düşük kırılma direnci ve kül düzeyine sahip olan tibia kemiğinin, ZTD sonrasında bu özelliklerinin önemli düzeyde iyileştiği belirlenmiştir (P<0,05). Araştırma sonuçları, ZTD uygulanan tavukların, uygulanmayanlara göre daha güçlü kemiklere sahip olduklarını ortaya koymaktadır (Arafa ve Harms, 1987; Gregory ve ark., 1991; Webster, 2003).

Çizelge 6. Tüy dökümü dönemi sıcaklığı, canlı ağırlık ve tüy dökümü döneminin yumurta tavuklarının bacak kemiği (tibia – femur) özellikleri üzerine etkisi[1]

Table 6. Effects of molting period temperature, body weight and molting period on traits of leg bones (tibia - femur) of laying hens

Uygulamalar	Özellikler									
	Tibia					Femur				
	Ağırlık (g)	Uzunluk (cm)	Çap (mm)	Kırılma direnci (N)	Kül (%)	Ağırlık (g)	Uzunluk (cm)	Çap (mm)	Kırılma direnci (N)	Kül (%)
Sıcaklık[2]										
Kontrol	9,93	12,07	10,34	118,6	34,79	6,93	8,57	9,97	148,4	37,17
Döngüsel sıcaklık	10,41	12,05	10,42	126,6	36,26	7,27	8,44	10,18	156,6	38,27
SEM[3]	0,261	0,071	0,087	4,397	1,084	0,216	0,101	0,182	7,54	1,954
Canlı ağırlık										
Hafif	9,01^{b}	11,86^{b}	10,18^{b}	110,8^{b}	35,10	6,28^{b}	8,48	9,84	135,6^{b}	38,84
Orta	10,57^{a}	12,13^{a}	10,35^{ab}	125,3^{ab}	34,87	7,48^{a}	8,32	10,38	154,5^{ab}	35,23
Ağır	10,94^{a}	12,20^{a}	10,62^{a}	131,8^{a}	36,61	7,53^{a}	8,71	10,00	167,4^{a}	39,01
SEM[3]	0,319	0,087	0,106	5,383	1,328	0,264	0,123	0,223	9,233	2,393
Tüy dökümü dönemi										
Başlangıç	10,13	12,02	10,23^{b}	107,3^{b}	32,92^{b}	7,08	8,49	9,98	149,4	35,91
Bitiş	10,22	12,10	10,53^{a}	137,9^{a}	38,14^{a}	7,11	8,52	10,17	155,6	39,53
SEM[3]	0,264	0,543	0,086	4,354	1,075	0,214	0,099	0,180	7,550	1,935
	Önemlilik (P)									
Sıcaklık (S)	0,206	0,841	0,496	0,206	0,346	0,266	0,390	0,403	0,445	0,692
Canlı Ağırlık (CA)	<0,001	0,023	0,022	0,028	0,605	0,002	0,098	0,233	0,041	0,450
Tüy Dökümü dönemi (TD)	0,812	0,448	0,021	<0,001	0,002	0,923	0,301	0,474	0,564	0,199
S × CA	0,307	0,284	0,508	0,841	0,383	0,561	0,368	0,350	0,736	0,733
S × TD	0,992	0,548	0,422	0,091	0,138	0,473	0,335	0,690	0,427	0,639
A × TD	0,793	0,335	0,839	0,620	0,531	0,863	0,220	0,969	0,918	0,753
S × CA × TD	0,504	0,340	0,215	0,801	0,573	0,401	0,343	0,653	0,731	0,098

[1]a-b: Aynı sütunda farklı harfleri taşıyan özellikler arasındaki farklar önemlidir (P<0,05), [2]Tüy dökümü döneminde tavuklara kontrol grubunda 24 saat süresince 21-22°C sıcaklık; döngüsel sıcaklık grubunda 10:00-18:00 saatleri arasında 32°C ve 18:00-10:00 saatleri arasında 21-22°C sıcaklık uygulanmıştır, [3]SEM: Ortalamaların Standart Hatası.

Bu olumlu etkinin ZTD sırasında kesilen yumurta veriminin, tavukların yapısal kemik bütünlüğünün yeniden oluşmasına imkan sağlamasından kaynaklanmaktadır (Hester 2017).

Sonuç olarak, verim yılını tamamlamış açlık uygulanmadan günde 60 g/tavuk kırılmış arpa verilerek uygulanan zorlamalı tüy dökümü programının tüm deneme gruplarında benzer bir sürede, üstelik herhangi bir tavuk ölümüne yol açmadan %25 CA kaybı hedefine ulaşılmasını sağlaması hayvan refahı açısından olumlu bir sonuç olarak değerlendirilmiştir. Uygulanan zorlamalı tüy dökümü programının yaz döneminde sıcağa bağlı olarak ortaya çıkan verim kaybı dışındaki diğer dönemlerde I. verim dönemi sonuna göre yumurta verimini ve ağırlığını, yemden yararlanma oranını, yumurta kalite özelliklerini ve bazı bacak kemiği özelliklerini iyileştirmiştir. Zorlamalı tüy dökümü döneminde uygulanan döngüsel yüksek sıcaklık, yeni verim döneminde kabuk kırılma direnci, haugh birimi ve ak indeksi gibi yumurta kalite özelliklerini iyileştirmiş, diğer yumurta kalite özelliklerini olumsuz etkilememiştir. Bu iyileşmenin, tüylerinin döküldüğü dönemde tavukların artan ısı ihtiyaçlarının zorlamalı tüy dökümü sırasında uygulanan sıcaklıkla karşılanmış olmasından mı ya da bir adaptasyon sonucunda mı meydana geldiği konusunda yeni çalışmalara ihtiyaç bulunmaktadır.

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DNA Barcoding and Phylogenetic Analysis of *Culex* and *Anopheles* Species in Siirt, Türkiye

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ABSTRACT

Mosquitoes play a critical role as disease vectors, making them significant in terms of both public health concerns and ecological balance. This study aims to identify mosquito specimens collected from Siirt city center and six different districts using morphological and molecular methods. A 658 bp fragment of the mitochondrial cytochrome c oxidase subunit 1 (*COI*) gene region was used for molecular diagnosis. The findings revealed four mosquito species: *Culex theileri* Theobald, 1903, *Culex mimeticus* Noè, 1899, *Culex quinquefasciatus* Say, 1823, and *Anopheles superpictus* Grassi, 1899. Mitochondrial gene PCR products were sequenced, and the sequences were uploaded to the NCBI database for public access. Phylogenetic analysis was conducted using these sequences to investigate the genetic distances and evolutionary relationships among the mosquito species. In the phylogenetic analysis, *Chironomus kiiensis* was used as an outgroup. The analysis revealed that *C. quinquefasciatus* and *A. superpictus* were had the highest genetic distance (0.16), while the closest genetic distance was observed between *C. quinquefasciatus* and *C. theileri* (0.06). This study is presented as a preliminary investigation into the genetic diversity, evolutionary relationships, and population dynamics of mosquito species in Siirt Province. Further studies with a larger sample size and additional sequences are needed to establish more comprehensive phylogenetic relationships. The molecular findings contribute significantly to the systematic and ecological studies of mosquitoes.

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Introduction

The order Diptera is one of the most species-rich and ecologically diverse groups of insects, consisting of approximately 130 families (Yeates & Wiegmann, 1999). Among these families, the Culicidae family comprises around 3,500 species across 41 genera worldwide (Foster & Walker, 2019). In Türkiye, recent studies on mosquito identification have reported the presence of 62 species belonging to 7 genera (Kuçlu & Dik, 2018). Mosquitoes of the subgenus *Culex* belong to the genus *Culex* Linnaeus, which has a broad global distribution and currently includes 203 recognized species (Somboon et al., 2023). The classification of the Culicidae family is shown below (Harbach, 2007):

- **Kingdom:** Animalia
- **Phylum:** Arthropoda
- **Class:** Insecta
- **Order:** Diptera
- **Family:** Culicidae
    - **Subfamily:**
        - **Anophelinae**
        - **Culicinae**

The taxonomic classification of the Culicidae family is illustrated in Figure 1.

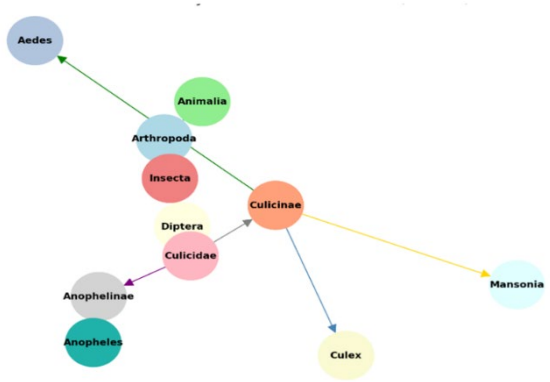

Figure 1. Taxonomic classification of the Culicidae family

Geographic region and ecological features are known to play a significant role in the distribution of mosquito species. Species that select various habitats show tolerance to environmental factors, while species that can breed in only a few habitat types tend to be less tolerant. Generally, species with high tolerance are more widely distributed and have higher population densities compared to other species (Eisen et al., 2008). Due to their specialized adaptation abilities, mosquitoes can thrive in a wide range of environments. Nearly every type of water source globally can serve as a breeding site for mosquitoes (Becker et al., 2010). As a result, mosquitoes are found worldwide and carry the diseases. They are absent only in specific regions of Antarctica, while especially coastal regions provide an ideal habitat for many mosquito species in Türkiye (Aldemir & Boşgelmez, 2006; Alten et al., 2000; Sengil et al., 2011).

Mosquitoes attract attention both in terms of health and economics due to their ability to survive for extended periods under unfavorable environmental conditions, rapidly reproduce in almost all aquatic habitats, and their presence in all zoogeographical regions (Smith et al., 2006). They have the potential to transmit pathogens that are significant to both human and animal health (Batovska et al., 2016). Mosquitoes, as biological vectors, transmit malaria, which is considered one of the most dangerous diseases, causing 500 million cases and approximately 2.5 million deaths globally each year (Hasan Muslu & Özbilgin, 2011). In Türkiye, malaria is most commonly found in southeastern provinces such as Diyarbakır, Batman, Siirt, Şanlıurfa, Mardin, and Şırnak, as well as in the Çukurova region. There is also a risk of malaria transmission from neighboring countries, such as Iran, Iraq, and Syria, where numerous cases of the disease occur (Smith et al., 2006).

Many studies have been conducted on the presence of mosquitoes, the activity of key species, their seasonal abundance, bio-ecology, and population development in various regions of Türkiye (Bişkin et al., 2010; Çetin & Yanıkoğlu, 2004; Demirci, 2006; Ede & Öztemiz, 2021; Eren et al., 1996; Günay, 2015; Oter et al., 2013; Sona & Değer, 2015; Şakacı, 2021).

The Botan Valley in Siirt province contains numerous natural streams, both large and small, and features still bodies of both natural and artificial water. In recent years, large dams constructed in and around Siirt have also begun to retain water. Additionally, the prevalence of septic pits due to insufficient sewage systems, along with extensive irrigation channels and wetlands, has led to frequent mosquito complaints throughout the year. As a result, authorities in Siirt annually employ chemical control methods to reduce mosquito populations.

Mosquito species in Siirt province pose a potential threat to human and animal health as vectors of pathogens. Therefore, accurate identification of these species is essential for effective monitoring and control. The high degree of similarity among mosquito species makes distinguishing them based on morphological characteristics challenging (Walton et al., 1999). Identifying mosquitoes remains a systematic issue, as it often relies on morphological features that can be difficult to interpret without specialized taxonomic expertise and are frequently lost during collection and storage (Versteirt et al., 2015). Molecular methods provide clear identification where morphological methods are inadequate. DNA data obtained from molecular studies can overcome the limitations of morphological approaches, enabling the identification of sibling and cryptic species (Hebert et al., 2003). DNA barcoding is widely recognized as a valuable molecular tool for the rapid and accurate identification and assessment of species and biodiversity (Heber et al., 2016). It has garnered broad interest due to its effectiveness and accuracy in identifying species of mammals, birds, reptiles, amphibians, fish, and arthropods (Chaiphongpachara et al., 2022). Compared to other molecular methods (RAPD, RFLP, AFLP, etc.), DNA barcoding offers several advantages. The primer set used in DNA barcoding (Folmer et al., 1994) aims to amplify a short fragment of the *COI* gene from many animal species (Yatkın & Güz, 2018). The mitochondrial cytochrome c oxidase subunit I (*COI*) gene, a conserved gene and the first standardized genetic region used for animal DNA barcoding, is the most popular barcode marker (Adeniran et al., 2021). DNA barcoding is a complementary species identification method with the potential to overcome current limitations. This study aims to identify mosquito species (Culicidae) in Siirt province and support morphological identification through DNA barcoding using molecular methods.

Materials and Methods

Mosquito Sampling

The study was conducted monthly from April to September in 2023 and 2024 in the wetlands of Siirt province. Sampling was carried out in Siirt Central District, Tillo, Kurtalan, Baykan, Eruh, Şirvan, and Pervari. Sampling was performed in wetlands such as dams, stagnant waters, rivers, and streams of various sizes in and around Siirt to represent the entire region. Aquatic habitats were selected based on their differences in ecological features such as location, size, status, fauna, flora, and turbidity. GPS coordinates are provided in Table 1. The mosquito sampling sites were mapped using ESRI ArcGIS Desktop 18.08 (Figure 2).

A plankton net with a mesh size of 153 microns was used for mosquito sampling. As described by Özgökçe et al. (2007) the plankton net was thrown randomly into the water while walking approximately 100 steps along a 1-5 m shoreline at a depth of 0.5-1.5 m.

Table 1. GPS Coordinates of Sampling Locations

No	Location	GPS Coordinates	
1	Siirt University	37°58'9.49"K	41°50'30.52"D
2	Siirt (Kezer Stream)	37°57'26.63"K	41°51'21.70"D
3	Siirt (Başur 1)	37°57'28.61"K	41°47'13.40"D
4	Siirt (Başur 2)	37°58'8.21"K	41°47'5.24"D
5	Siirt (Ziyaret 1)	38° 0'58.64"K	41°46'33.52"D
6	Siirt (Ziyaret 2)	38° 0'53.78"K	41°46'36.59"D
7	Baykan 1	38° 6'37.81"K	41°43'6.67"D
8	Baykan 2	38° 6'35.83"K	41°42'58.43"D
9	Kurtalan	37°55'50.45"K	41°42'41.04"D
10	Siirt Central 1	37°57'6.99"K	41°53'27.55"D
11	Siirt Central 2	37°51'35.14"K	41°53'19.58"D
12	Siirt Central 3	37°54'26.67"K	41°56'40.53"D
13	Eruh (Zarova Stream)	37°48'36.56"K	42°10'35.02"D
14	Şirvan 1	38° 1'19.14"K	41°56'4.03"D
15	Şirvan Dam (Stream)	38° 2'15.09"K	41°57'25.96"D
16	Şirvan Dam	38° 2'31.64"K	41°57'26.06"D
17	Şirvan Trout Facility	38° 3'13.15"K	42° 1'38.81"D
18	Şirvan 2	38° 3'50.04"K	42° 1'38.60"D
19	Şirvan Taşköy Trout Farm	37°58'49.42"K	42° 8'28.65"D
20	Siirt Limak Dam	37°56'13.89"K	42°14'22.87"D
21	Pervari Gölköy	37°56'38.91"K	42°25'6.20"D

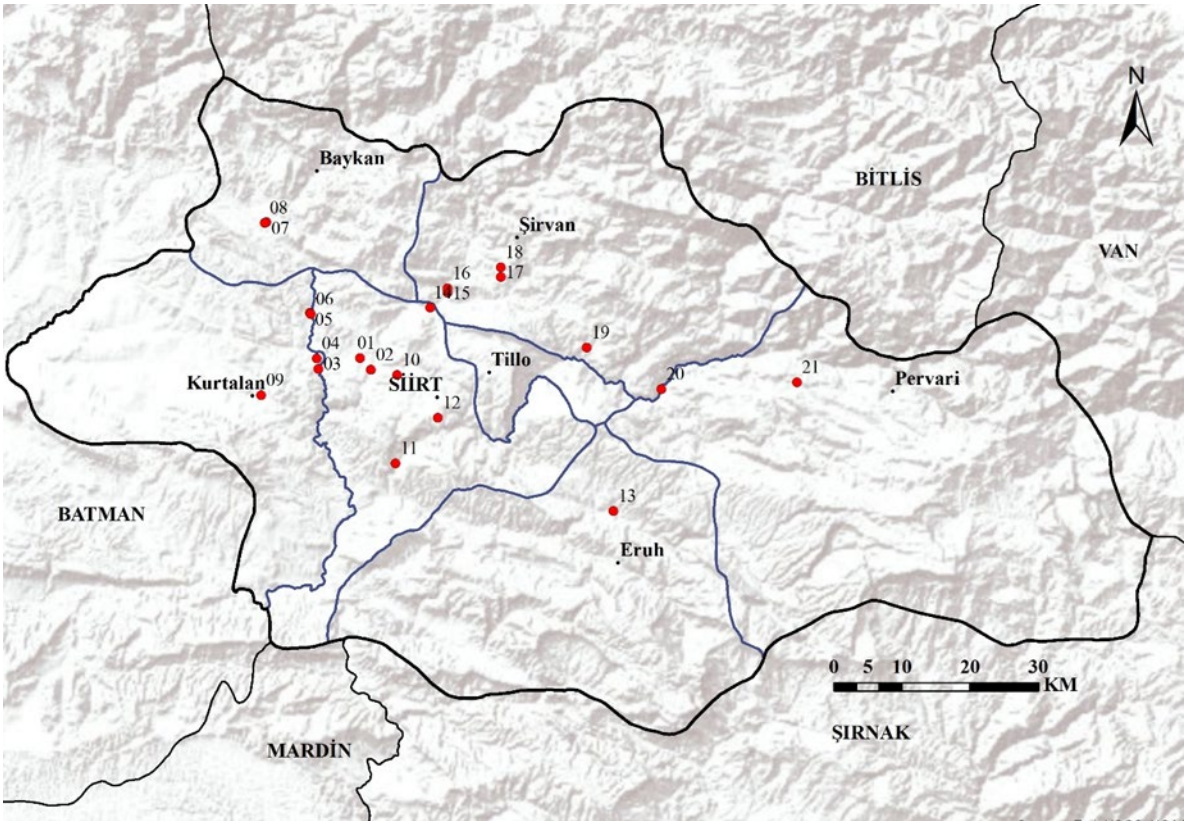

Figure 2. Mosquito sampling sites in and around Siirt Province.

The larvae collected in the net's sampling container were transferred into lidded plastic collection jars and transported to the laboratory under a cold chain. The net was manipulated by pulling and releasing the attached rope during the walk to ensure the net reached both surface and bottom areas. Additionally, mosquito larvae were collected from various water sources, such as shallow wetlands and pools, using plastic scoops, and were later brought to the laboratory in plastic containers. A large number of larval specimens were collected during the sampling process.

Morphological Identification

The collected larvae were kept in white plastic trays (25x30x5 cm) under controlled laboratory conditions (25-28°C, 12:12 light-dark cycle, 50-60% relative humidity). Individuals that reached the pupal stage were transferred to containers and monitored until they developed into adults. The adult mosquito species were identified according to Azari-Hamidian & Harbach (2009), Cranston et al. (1987), Darsie & Samanidou-Voyadjoglou (1997), and DuBose & Curtin (1965). Photographs of the mosquitoes were taken

using an Olympus SC61 stereo microscope with an Olympus SC50 camera and CellSens Entry software. All larval and adult mosquito samples identified morphologically were preserved in 96% ethanol in centrifuge tubes (one specimen per tube) and stored at -20°C for molecular analysis.

DNA Isolation and PCR Procedures

DNA isolation of the morphologically identified mosquito species was performed using the Invitrogen DNA PureLink™ Genomic DNA Mini Kit. Insects were ground thoroughly in liquid nitrogen with metal pestles, and total genomic DNA was extracted following the kit protocol. The quantitative and qualitative properties of the extracted DNA were evaluated using a Nano-400A spectrophotometer and agarose gel electrophoresis, respectively. The mitochondrial cytochrome c oxidase subunit I (*COI*) gene region was amplified using PCR (MiniAmp Plus Cycler) with universal primers LCO1490-F (5'-GGTCAACAAATCATAAAGATATTGG-3') and HCO2198-R (5'-TAAACTTCAGGGTGACCAAAAAATCA-3') (Folmer et al., 1994). The PCR cycle included 1 min pre-denaturation at 95°C, followed by 35 cycles of denaturation at 95°C for 30 sec, annealing at 55°C for 30 sec, and elongation at 72°C for 60 sec, with a final extension step at 72°C for 10 minutes. PCR products were analyzed using 1% agarose gel electrophoresis, prepared by dissolving agarose in 1x TAE buffer. The gel was run at 100 volts for around 45 minutes. To estimate the size of the PCR products, a 100 bp DNA ladder was included as a molecular weight marker. Following electrophoresis, the gel was stained with ethidium bromide for 20 minutes, and DNA fragments were observed under UV light. The PCR products were sent for sequencing.

DNA Sequence Analysis of PCR Products

The PCR products of the *COI* region were sequenced using the Sanger method by a commercial company. The sequence data were processed using software such as MEGA X for phylogenetic analysis (Kumar et al., 2018), where the alignment of sequences was performed, and genetic distances between the species were calculated. Additionally, ChromasPro (Version 2.1.10) (Technelysium Pty Ltd, South Brisbane, Australia) was used for sequence visualization and editing, BioEdit (Version 7.2.5) (Hall, 1999) was utilized for sequence alignment, and CLC Main Workbench (v6.7.1) (Matvienko, 2015) was employed for further data manipulation and analysis (Figure 3).

Phylogenetic Analysis

DNA sequences were visualized using ChromasPro (Version 2.1.10) and saved in FASTA format. The forward and reverse complement reads of the sequences were aligned and compared using BioEdit (Version 7.2.5) (Hall, 1999). For each insect species, *COI* gene sequences were uploaded in FASTA format to NCBI Nucleotide BLAST, and their similarities with sequences in the NCBI database were compared. The most similar sequences were noted with their GenBank accession numbers and used for the phylogenetic tree construction. Sequences from our study and *COI* gene sequences of insect species obtained from NCBI Nucleotide were uploaded to CLC Main Workbench (v6.7.1) (Matvienko, 2015) and MEGA X (Kumar et al., 2018) to determine modeling methods and distances. Phylogenetic trees were constructed using the Maximum Likelihood method.

Results and Discussion

In this study, three different mosquito species belonging to two genera that were previously unrecorded from Siirt Province are identified. The identified species are: *Culex mimeticus* Noè, 1899, *Culex theileri* Theobald, 1903, *Culex quinquefasciatus* Say, 1823, and *Anopheles superpictus* Grassi, 1899.

Culex mimeticus is a mosquito species belonging to the genus *Culex*, first described from specimens collected in Grassano, located in the southern part of Basilicata, Italy (Noè, 1899). It has been distributed from the southwestern Palearctic region eastward to the Eastern region (Somboon et al., 2021). *C. mimeticus* is a medium-sized species that can be easily distinguished from closely related species by the presence of three distinct yellowish areas on the costa of the wing and pale areas on other veins. In the fourth instar larvae of this species, seta 2-S is long and curved, seta 7-I is typically single and as long as 6-I. The distal pecten spines possess seven or more ventral denticles. The pre-clypeal seta is thick and significantly thicker than the inner and median branches of the setae. The siphonal trachea is narrow and less than half the width of the siphon (Azari-Hamidian & Harbach, 2009; Harbach, 1988) (Figure 4).

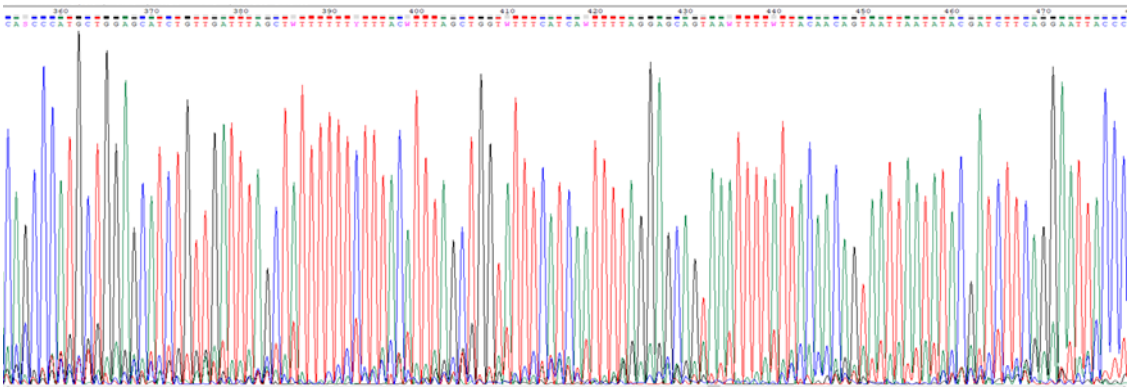

Figure 3. Chromatogram Image of DNA Sequence from Mosquito Species

Figure 4. Image of *Culex mimeticus* larva under the microscope

Figure 5. Image of *Culex theileri* larva under the microscope

Culex mimeticus prefers to breed in wetlands and stagnant water bodies. It can also be observed in urban and rural areas, making it a widespread species across a wide range of habitats (Harbach, 2018). This species may have the potential to act as a vector for some diseases, but further research is needed to determine whether it poses a health risk as significant as other *Culex* species. *C. mimeticus* has been identified as a previously unrecorded species in the region based on morphological and molecular analyses conducted in Siirt Province. The definitive identification of the species has been carried out using molecular analyses and DNA barcoding methods. This species has been found particularly abundantly in stagnant ponds located in the Şirvan and Pervari districts. The presence of *C. mimeticus* in these breeding sites is significant for understanding mosquito diversity and potential health risks in the region. The morphological and molecular findings indicate that this species contributes to the ecosystem dynamics in Siirt Province and plays a critical role in assessing health risks.

Culex theileri is a mosquito species belonging to the *Culex* genus, identified in this study. This species exhibits a broad distribution across the Afrotropical, Southern Palearctic, and Northeastern regions. It has been reported in several European countries including Portugal, Spain, France, Italy, Yugoslavia, Greece, Hungary, Bulgaria, and Ukraine (Demirci et al., 2012). Morphologically, it can be easily distinguished by the presence of postspiracular and prealar scales, along with white anterior banding on all tibiae and the fore and middle femora. The basal yellow banding of the abdominal tergites typically manifests as triangular patches towards the posterior. In the fourth instar larvae of this species, the siphonal tuft arises near the posterior midline of the siphon and consists of 4–11 branches. The siphonal trachea is broad, measuring more than half the width of the siphon. The distal pecten spines are very large and curved. Seta 1-C is dark, relatively thick, and never sharply tapered or filamentous (Azari-Hamidian & Harbach, 2009; Harbach, 1988) (Figure 5). Female individuals engage in blood-feeding behavior and often target humans (Theobald, 1901). *Culex theileri* prefers to breed in wetland areas and stagnant water bodies, and it can also be observed in urban and rural environments. The species is particularly prevalent in humid and warm climates (Harbach, 2018). Like other *Culex* species, it may act as a vector for various pathogens. In fact, Azari-Hamidian & Omrani (2022) reported that *C. theileri* serves as a vector for avian Plasmodium, *Dirofilaria immitis*, West Nile virus, Japanese encephalitis virus, and some insect-specific flaviviruses across multiple countries. *Culex theileri* has been identified as a new record for Siirt Province based on both morphological and molecular analyses (Figure 5). This species has been primarily found in stagnant water bodies, pools, and ponds within the province. Morphological analyses highlight the physical characteristics of *C. theileri*, while molecular methods, including DNA barcoding, confirm its accurate identification and genetic details. Its presence in Siirt offers valuable insights into the region's ecosystem dynamics and mosquito diversity, making these findings crucial for ecological research and the evaluation of health risks.

The other significant mosquito species identified in our study is *C. quinquefasciatus*. This species is primarily found in tropical and subtropical regions worldwide (Becker et al., 2010). Morphologically, *C. quinquefasciatus* exhibits somewhat light brown scutum scales that are relatively long and sparse. The subcostal vein typically intersects with the costa before the R_{2+3} fork, prealar scales are absent, and the basal bands of abdominal tergites range from whitish to cream in color. In the fourth instar larvae of this species, the siphon is generally widest in the middle and tapers more towards the apex compared to the base. The siphon width at the apex is approximately half the width of the base. Seta 1-III and 1-IV are single (Azari-Hamidian & Harbach, 2009; Harbach, 1988) (Figure 6). *Culex quinquefasciatus* generally prefers to breed in stagnant water bodies, wetlands, channels, and other water sources. It can also be found in urban and rural areas, particularly near human settlements. This species is more prevalent in warm and humid climates (Harbach, 2018). Furthermore, *C. quinquefasciatus* is known as a vector for microfilarial parasites (Benelli et al., 2017) and has been identified as a primary vector for the Saint Louis encephalitis virus and West Nile virus (Samy et al., 2016). This makes this species significant from a public health perspective. *Culex quinquefasciatus* has been detected in stagnant and polluted water bodies as well as irrigation pools in Siirt Province Morphological and molecular analyses conducted in Siirt have identified this species as a new record for the region.

Figure 6. Image of *Culex quiquefasciatus* larva under the microscope

Figure 7. Image of *Culex quiquefasciatus* larva under the microscope

Table 2. BLASTn results of the obtained sequences in the NCBI GenBank

No	NCBI Accession Number	Species	NCBI- BLAST	Similarity
1	PQ631176	*Culex theileri*	KF407830.1 -*Culex theileri*	%99.05
2	PQ631175	*Culex mimeticus*	MW961280.1-*Culex mimeticus*	%99.03
3	PQ631177	*Culex quinquefasciatus*	NC014574.1 -*Culex quinquefasciatus*	%95.62
4	PQ631174	*Anopheles superpictus*	MT993498.1 -*Anopheles superpictus*	%99.52

Finally, *A. superpictus* has been identified. This species, a Palearctic mosquito from the genus *Anopheles*, is commonly found across the Middle East, Mediterranean region, Africa, and parts of Asia (Hanafi-Bojd et al., 2018). *Anopheles superpictus* is a large, pale species characterized by broad yellow scales in the middle of the scutum. It lacks upper proepisternal setae, and there are one or two yellow spots at the base of the costa. Notably, there is no dark spot at the tip of the cubitus bifurcation, and the fringes at the wing tip are mostly yellow, except for a small dark area between R_2 and R_3. In the fourth instar larvae of this species, prothoracic seta 1 is small and slightly sclerotized with tubercular structures. Prothoracic setae 1 and 2 are not fused, and the base of the dorsal apotome is marked with dark spots (Azari-Hamidian & Harbach, 2009) (Figure 7). *Anopheles superpictus* particularly prefers to breed in wetlands and stagnant water bodies. Agricultural fields, channels, and irrigation systems are among the breeding sites for this species. Additionally, it is common in warm and humid climates (Harbach, 2018). *Anopheles superpictus* is known as a carrier of malaria parasites and plays a role in the transmission of *Plasmodium* species, making it a significant target for malaria control programs (Aytekin et al., 2009). In our study, *A. superpictus* was notably detected in wetlands, stagnant ponds, and irrigation systems. This finding provides crucial insights into the diversity of mosquito species in the region and is critical for assessing potential health risks.

The identification of mosquito species through classical taxonomy based on physical characteristics is often challenging and time-consuming. Furthermore, morphological traits exhibit minimal variation among species (Aung et al., 2023). In this context, the DNA barcoding method is beneficial in supporting these identifications, as it aids in accurately distinguishing between species. Genetic analyses performed on samples from the Culicidae family collected in Siirt Province involved the amplification of a 658 bp fragment of the mitochondrial cytochrome c oxidase subunit 1 (*COI*) gene using PCR. The sequence data related to the species that underwent morphological identification were obtained through DNA barcoding and compared with other species in the database via BLASTn in the NCBI GenBank. The results of the comparisons are presented in Table 2.

Based on the results of the sequence analysis, four different mosquito species have been identified in Siirt Province. These include *C. theileri, C. mimeticus*, *C. quinquefasciatus* and *A. superpictus* . The PCR products for these four mosquito species were examined for quality and quantity through agarose gel electrophoresis, confirming that the size of each PCR product was 658 bp..

Genetic analyses utilizing a region approximately 650 base pairs in length from the *COI* gene region revealed the evolutionary relationships and genetic distances among these mosquito species. In the phylogenetic tree, *Chironomus kiiensis* (Diptera) was used as an outgroup to ensure the accuracy of the analyses. The genetic distance of this species from the other mosquito species served as a reference point for the rooting of the phylogenetic tree. The sequences from NCBI that showed the highest similarity in the BLAST comparison were visualized along with their accession numbers (Figure 8), allowing for an understanding of the closeness of the species to one another.

The phylogenetic tree illustrates the genetic relationships and evolutionary distances among the analyzed species, including *C. theileri*, *C. quinquefasciatus*, *C. mimeticus*, and *A. superpictus*, with *C. kiiensis* used as the outgroup. Close genetic relatedness is observed among the *Culex* species, while *Anopheles superpictus* occupies a more distant branch, indicating its genetic divergence from the *Culex* genus. Branch lengths represent genetic distances, while the bootstrap values, indicated in red, reflect the reliability of the respective branches.

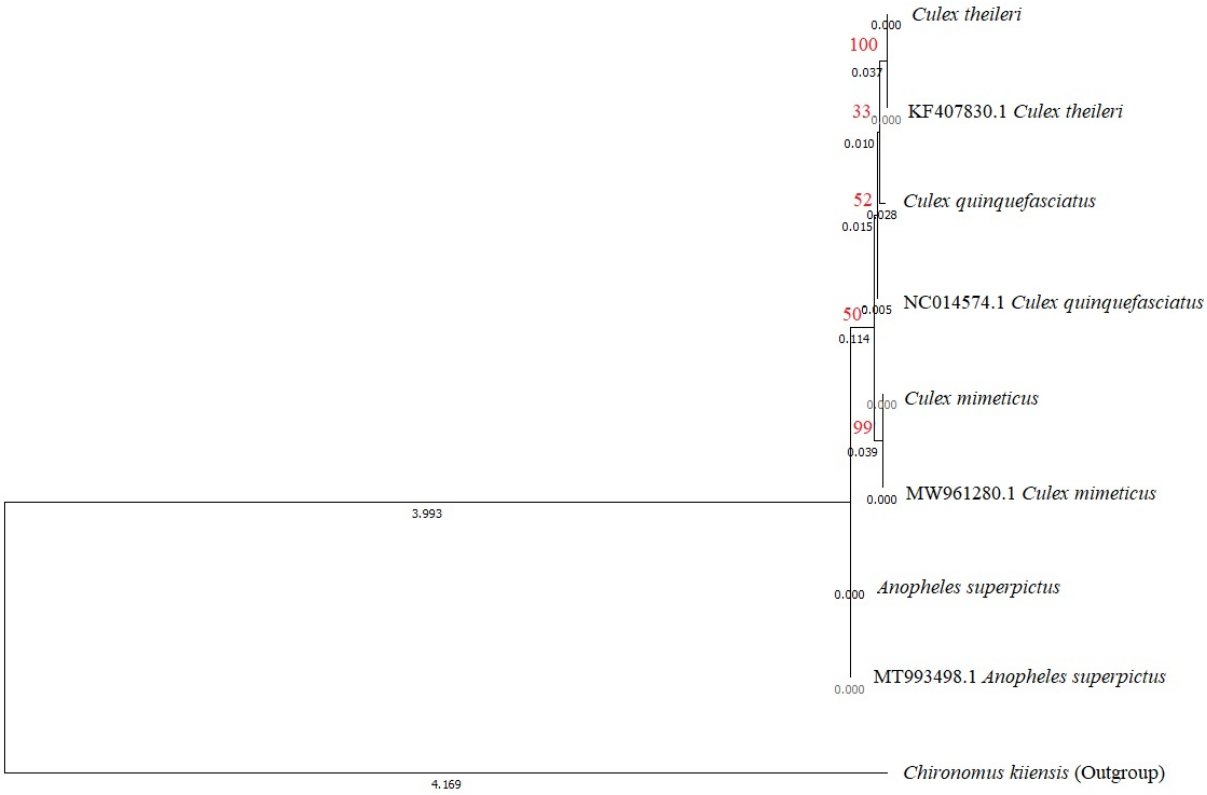

Figure 8. Phylogenetic relationships among mosquito species and closely related taxa (Maximum Likelihood).

For instance, the relationship between individuals of *C. theileri* is strongly supported with a bootstrap value of 100%, whereas the relationship for *C. quinquefasciatus* is less robust, with a bootstrap value of 52%. Additionally, the outgroup, *C. kiiensis*, demonstrates a more distant evolutionary relationship to the other species. The values presented as "0.000" in the figure denote the minimal genetic distance at specific nodes, suggesting either identical or nearly identical genetic sequences between those taxa. These values are indicative of high genetic similarity rather than complete absence of divergence. Overall, this tree highlights close evolutionary relationships within the *Culex* genus while emphasizing the distinct divergence of *A. superpictus*. The molecular results illustrate the genetic differences and evolutionary relationships among the mosquito species identified in Siirt Province. The phylogenetic tree indicates that species within the *Culex* genus are genetically closer to each other, while *A. superpictus* occupies a more genetically distant position within this group. Furthermore, the low genetic distance between *C. theileri* and *C. quinquefasciatus* supports the notion of an evolutionary relationship between these two species (Figure 8).

The findings of this study shed light on the genetic diversity and evolutionary relationships of mosquito populations in Siirt Province. Mosquitoes, particularly species belonging to the *Culex* and Anopheles genera, possess significant potential as disease vectors. The four species identified in our study (*C. theileri*, *C. mimeticus, C. quinquefasciatus,* and *A. superpictus*) pose risks to human health and contribute to ecosystem balance. These results are crucial for understanding regional population dynamics and strategically planning mosquito control efforts.

DNA barcoding is a widely recognized molecular biological approach due to its effectiveness and accuracy in identifying species across mammals, birds, reptiles, amphibians, fish, and arthropods (Chaiphongpachara et al. 2022). DNA barcoding relies on the amplification of a highly conserved and standardized short DNA region (approximately 400-800 base pairs using PCR for species-level taxonomy (Yang et al., 2018). In recent years, molecular techniques have gained increasing importance for the accurate and rapid identification of species. For this purpose, molecular techniques involving various genetic markers such as *COI*, *COII*, *Cyt b*, *ITS1*, and *ITS2* have been proposed as complementary tools to morphological species identification (Adeniran et al., 2021). The *COI* gene region employed in molecular analyses is a commonly preferred method for determining genetic differentiation among various insect species (Hebert et al., 2003). The utilization of the 658 bp segment of *COI* ensures that our study aligns with existing literature and facilitates international comparisons. The PCR products obtained, measuring 658 bp, confirm the successful amplification of the target region and accurate species identification. The *COI* gene used in our study is reported to be one of the most conserved mitochondrial genes, offering significant advantages for taxonomic studies (Roe & Sperling, 2007). In this context, numerous studies utilizing DNA barcoding with the *COI* gene have conducted identifications and phylogenetic analyses of mosquitoes (Adeniran et al., 2021; Chaiphongpachara et al., 2022; Daravath et al., 2015; Hernández-Triana et al., 2019).

The results of the phylogenetic analyses reveal the genetic relationships among *Culex* and *Anopheles* species, highlighting their evolutionary divergence. Notably, the

minimal genetic distance (0.000) between individuals of *C. theileri* indicates a high level of genetic similarity within this species. Similarly, the close relationship between *C. mimeticus* and *C. quinquefasciatus* (genetic distance of 0.039) suggests a shared evolutionary history, offering valuable insights into their potential ecological interactions and habitat overlap. Similarly, the position of *A. superpictus* on a more distant lineage compared to *Culex* species suggests that these two genera have followed different evolutionary pathways (Harbach, 2007).

Conclusion

In summary, this study provides valuable insights into the mosquito species in Siirt Province, documenting new records and verifying species identification through morphological and *COI* gene analyses. These findings enhance the existing knowledge on regional mosquito diversity and provide a solid baseline for future taxonomic and molecular studies. Documenting new records in this region contributes to a more comprehensive understanding of the biodiversity in Türkiye, supporting future research focused on regional species identification and distribution.

Declarations

Author Contribution Statement

Halil Dilmen: Project administration, supervision, conceptualization, methodology, review and editing, and molecular analysis.

Behcet İnal: Laboratory work, data collection, investigation, and molecular analysis.

Mehmet Salih Özgökçe: Data evaluation and analysis.

Mustafa Cemal Çiftçi: Field sampling, species identification, and investigation.

Hilmi Kara: Molecular analysis.

Sedriye Çatkın: Field sampling and data collection.

Meryem Özer Dilmen: Laboratory work and data collection.

Gülcihan Koyunçu: Field sampling and data collection.

Fund Statement

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Conflict of Interest

No potential conflict of interest was reported by the author(s).

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Will Olive Groves have a Future Under Climate Change Conditions in The North Aegean Sub-Region, a Mediterranean Agricultural Ecosystem of Türkiye?

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ABSTRACT

The study is aimed at investigating future changes in sustainability of olive farming by means of climate change, and changes in agricultural climatic suitableness and phenology of olive tree cultivation in the North Aegean sub-region of Türkiye mainly characterised with dry summer subtropical Mediterranean climate. According to projected changes based on RCP8.5 scenario, projected warming reaches an average of 5-6°C increase indicating most negative condition on olive cultivation. According to RCP8.5 scenario annual precipitation projections, present suitable areas of olive groves will decrease in the period of 2049-2073, and almost the entire study area will be in the category of medium suitable. With respect to projected Emberger Bioclimate classification, for RCP 8.5 scenario, there will be a significant increase in dry-sub humid areas in the period of 2049-2073. This increase will cover up the coastal areas in the period of 2074-2098, and even all the study region will be very likely characterised with dry-sub humid and semi-arid Mediterranean bioclimatic types except for some coastal areas. An increase of about 6°C is expected in maximum values of maximum air temperatures during the bud swelling periods in the spring, especially after 2050 under RCP8.5 scenario. This increase in extreme maximum temperatures may cause olive trees to bloom earlier and prolong the growth period. By regarding the high vernalization requirement of main olive variety in the study area, a 6°C temperature increase may significantly decrease olive yields and will force farmers to transition to new varieties with relatively low vernalization requirements. According to both RCP scenarios, there is a possibility of extension of suitable areas for olive cultivation towards low to mid-elevation plateaus and mid-elevation slopes of mountainous areas and high plateaus particularly facing suitable aspects to lower negative effects of projected future warming and dryness.

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Introduction

Climate change will likely reduce crop yields in many regions of the great Mediterranean basin, mainly because of increased air temperatures affecting crop phenology and the shortening of the crop growing season (Ali et al., 2022). In this context, the shortening of the growing season is possible in some cases and in some sub-regions, agricultural basins, etc. Although it may reduce the need for irrigation, additional irrigation will be needed for many crops (Saadi et al., 2015; Tas, 2021; An et al., 2023). In Egypt, Libya, Tunisia, Algeria, Morocco, Syria, Malta and Lebanon, water availability is currently below or approaching 1,000 m^3 per capita per year, the common benchmark for water scarcity (Türkeş et al., 2011). Mediterranean countries such as Spain, Greece, Türkiye and Italy are increasingly facing regional water shortages due to the problems of climate change and increasing climatic variability and the increasing demand for water in various socioeconomic sectors (e.g. drinking water, agriculture and irrigation, energy, etc.) (Türkeş et al., 2011; Öztürk et al., 2018; Tramblay et al., 2020; Ali et al., 2022, etc.)

The olive plant probably originates from the Eastern Mediterranean region of the Middle East. *Olea europaea* L. (European olive), from the Oleaceae family, is traditionally found in the Mediterranean Basin, except for the mountainous areas with its unique mountain climate and ecosystem, characterized mainly with dry and hot summer and wet winter subtropical Mediterranean climate and semi-arid and dry subhumid step climate (Türkeş, 2020; Türkeş, 2021, 2022). Olive farming and olive-related production types are a very important agricultural activities due to its high socioeconomic, traditional and

environmental importance particularly in the Mediterranean countries. Climate change causes significant changes in the natural variability of the climate and increases the frequency and severity of extreme weather and climate events and disasters. Therefore, it is expected that this negative aspect of climate change will also make itself felt in the olive growing sector.

The possible effects of climate change can affect the olive trees and the sustainability of olive farming. For productive olive cultivation, annual precipitation should be more than 600 mm (Gucci & Fereres, 2012). Low, high, and extreme values of temperature negatively affect the growth, quality, and yield of olives (Tuğaç & Sefer, 2021). Because higher temperatures and more frequent and severe heat waves around flowering will likely affect phenology, whereas suitable areas for olive cultivation could extend northward and to higher elevations under the A1B scenario in 2036–2065 (Tanasijevic et al., 2014), negative consequences of climate change for several countries are expected, including southern Spain (Gabaldón-Leal et al., 2017; Arenas-Castro et al., 2020) and Tunisia (Ouessar, 2017) under 2°C warming. Under 1.5°C to 2°C global warming levels, olive yields in the northern Mediterranean regions could decrease by up to 21% (Brilli et al., 2019; Fraga et al., 2020). On the other hand, another regional study (Bouregaa, 2019) suggests that a 3°C warming could cause a 15–64% drop of the production of rain-fed olives in Algeria.

Studies in the literature mainly focus on simulating plant growth models to investigate the climate change effects on olive biomass growth, soil properties and fruit productivity (Lorite et al., 2018; Viola et al., 2013). Also, the impacts of future changes in climate variables on olive plants is another challenging topic studied by scientists nowadays (Gabaldón-Leal et al., 2017). After determining the impacts of climate change on olive plants, researchers investigate the possible adaptation strategies against the potentially negative impacts of climate change (Fraga et al., 2021). In Türkiye, only a few studies focused on determining suitable olive cultivation areas based on ecological demands and phenological stages. Tuğaç & Sefer (2021) and Bilgilioğlu (2021) used multi-criteria decision analysis (MCDA) methods and geographic information systems (GIS) for determining suitable olive cultivation areas. In a more recent study, Ozalp & Akıncı (2023) performed random forest (RF) analysis combined with GIS to determine suitable olive cultivation areas. This is the first study in literature investigating the possible impacts of future climate change in Türkiye. The other studies in the literature focused on determining genotypes, genetic diversity, and pomological properties (Yıldırım et al., 2017; İpek, 2009, 2016; Sakar et al., 2016), demonstrating areas with olive trees (Efe et al., 2013; Öztürk et al., 2021), fruit and oil characteristics of olive plant (Özdemir et al., 2016).

However, the effect of future climate change on the olive plant in Türkiye is a very important research question and remains unanswered yet. Thus, phenological stages of oil plant were evaluated from the olive tree phenology information of the Turkish Meteorological Service (TMS) and present and future climatic suitability of olive cultivation (i.e., olive groves) lands were determined according to modified thresholds of the suitability criteria exist in the literature.

In this study, which is very likely the first peer-reviewed article study conducted in Türkiye, the future (2024-2098) changes in various precipitation and air temperature variables (i.e., climatic impact drivers) along with a bioclimatic index and various specific indicators related to olive cultivation, were examined in comparison with present conditions. First, the current climate conditions of the study area were analyzed in detail to evaluate the effects of climate change accurately. Then, olive grove lands concerning present land cover characteristics related to major geomorphological units were evaluated in detail. Later, various climate indices and indicators were calculated by making use of projected climatic time series based on the previous RCP4.5 and RCP8.5 climate scenarios of the Intergovernmental Panel on Climate Change (IPCC, 2013), and the future climate of the study area was examined for the different phenological stages of the olive trees. Unlike the studies in the literature, a very high-resolution data set was used to investigate present climate conditions and the distribution of the suitable olive (*Olea europaea* L.) cultivation areas.

Since olive trees adapt very well to the Mediterranean climate, and the olive is a climax plant of the Mediterranean climate and biome, the Mediterranean bioclimate layers of the study area were determined using Emberger's Pluviothermic Quotient (Q) and the future change was determined according to the RCP4.5 and RCP8.5 climate scenarios of the IPCC (2013). Through that, the changes in the Mediterranean bioclimate layers were examined and how olive groves would be affected in the future was evaluated. This approach provided more information about the effect of climate change because larger intervals between the thresholds defining climate classes existed in the original version of Emberger climate classification. In addition, the areas suitable for olive cultivation and the future situation were investigated based on the suitableness variables selected by Tuğaç & Sefer (2021) considering expert opinion and literature reviews. The phenological periods were considered while selecting variables and threshold values in determining the growing conditions of the olive trees.

Materials and Methods

Study Area

The study area is located between latitudes 38.9 - 39.6 and longitudes 26.3 - 27.7 (Figure 1 and 2). The influence of the dry summer and rainy winter subtropical Mediterranean climate is observed in the entire study area, which covers mainly the North Aegean sub-region of Türkiye (Türkeş, 2022). Regarding the aridity or humidity indices, the North Aegean sub-region of Türkiye is characterized mainly by moist- and dry sub-humid climates except the coastal mountainous areas like Kaz Dağı (Mount Ida) with a humid climate north of Edremit Bay (Figure 1) (Türkeş, 2022). The topographic structure of the study area shows great changes in short distance. In addition, the orographic structure of the region allows the effects of the sea to penetrate the interior through the valleys (grabens) between the mountains (Figure 1).

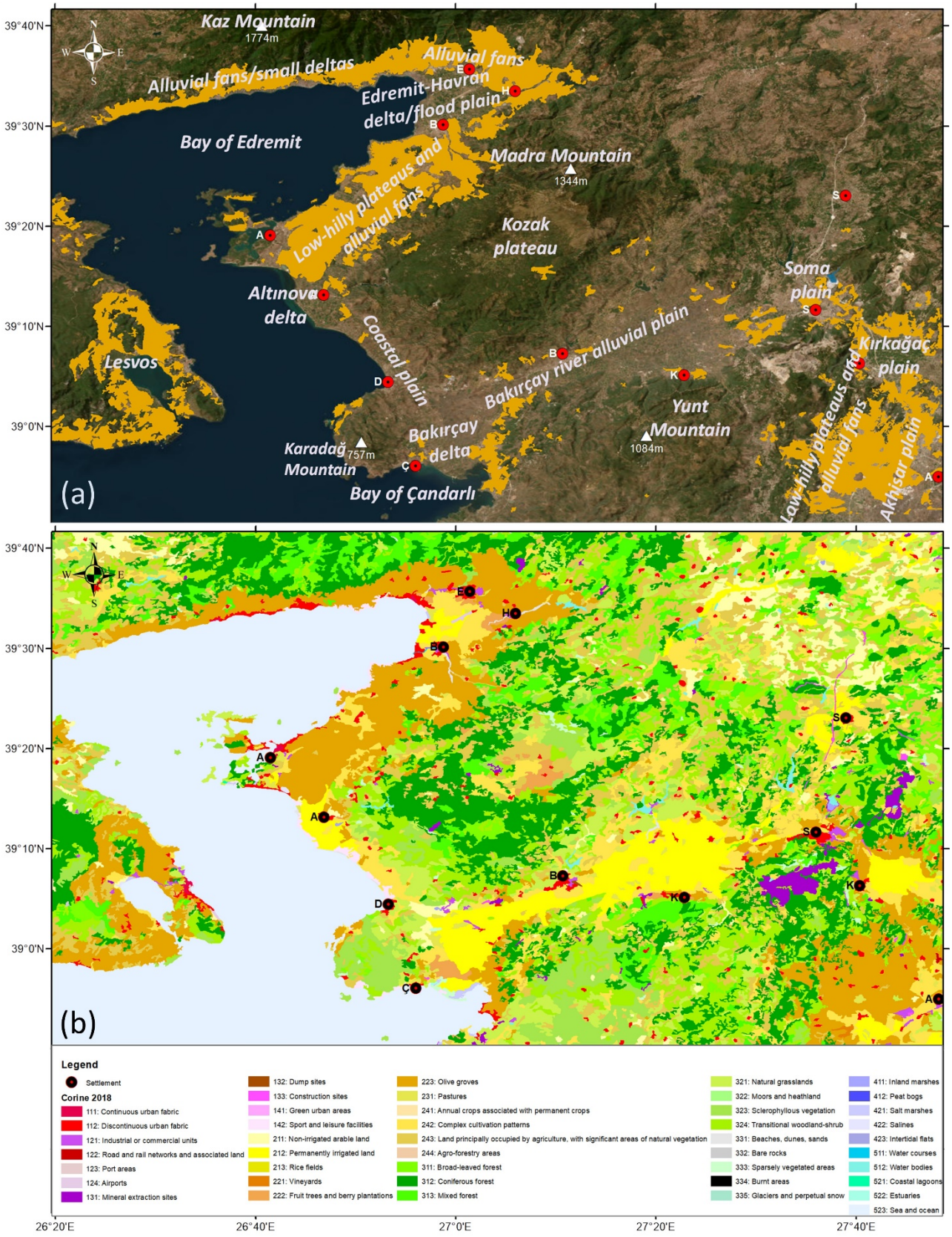

Figure 1. Geographical distribution patterns of (a) the prominent olive grove lands and associated major agro-geomorphologic units geographically belonging to mainly Balıkesir and Manisa districts of the North Aegean sub-region in Türkiye, and of (b) Corine land cover classes over the North Aegean olive groves sub-region, both of which are prepared based on the CLC2018 data.

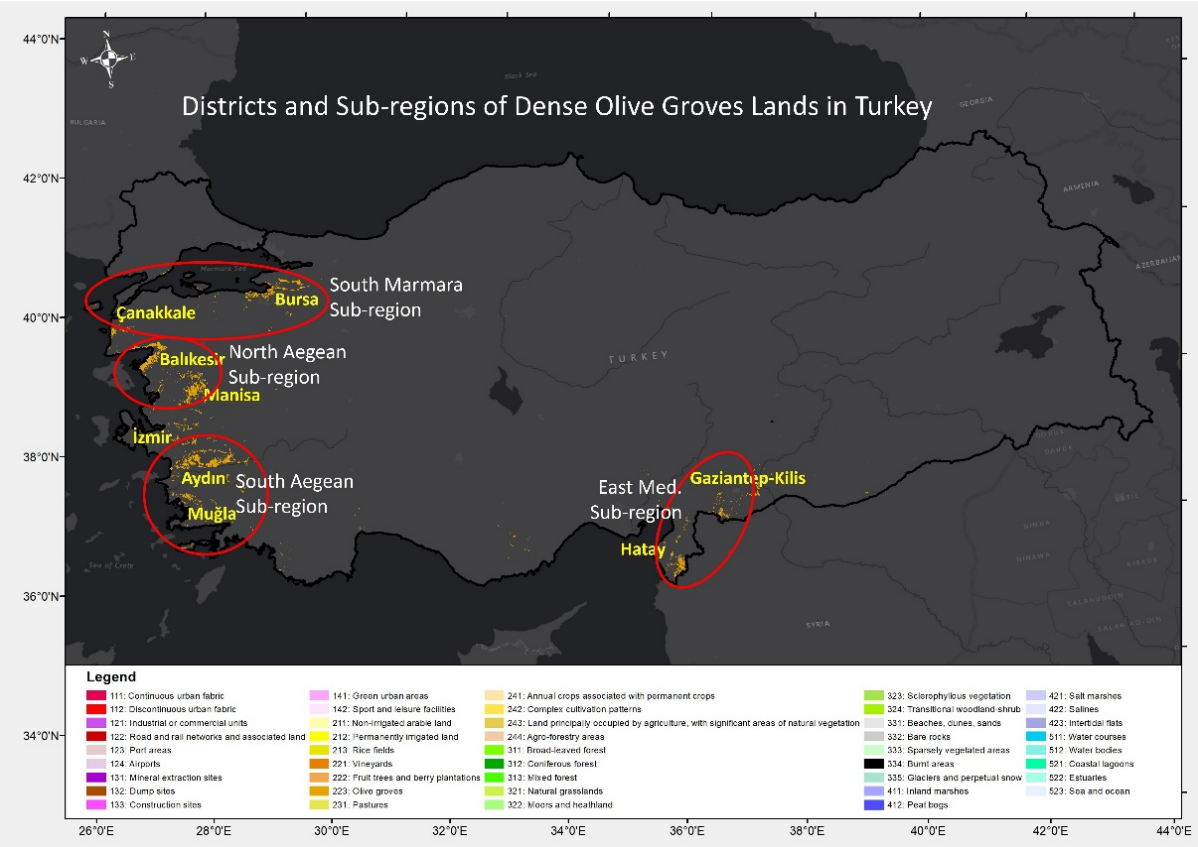

Figure 2. Spatial distribution patterns of prominent olive districts (yellow) and sub-regions (red circle) determined by dense olive groves lands in Türkiye based on the CLC2018 data.

Data Sources

Land cover data

The maps given in Figure 1 and Figure 2 were prepared by making use of the Corine Land Cover (CLC) data (CLC2018, Version 2020_20u1). CLC2018 is one of the datasets produced within the frame of the Copernicus Land Monitoring Service referring to the land cover/land use status of year 2018. CLC provides consistent and thematically detailed information on land cover (LC) and LC changes (LCC) over Europe. CLC datasets are rooted on the patterns of satellite imagery produced by researchers of participating countries; EEA members and cooperating countries (EEA39).

Present climate data

Since the study area is geographically small (North Aegean sub-region), a very high-resolution dataset is needed to spatially investigate the current and future climate variables. Since meteorology measurement stations are few, they are not preferred in this study as they will represent the study area spatially.

Re-analysis data from the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5-Land (Hersbach et al., 2020) was used to examine the current climate condition of the study area. Re-analysis is simply an approach that combines past short-term weather forecasts with observations through data assimilation. ERA5-Land provides hourly high-resolution (~9km grid interval) information on surface parameters. ERA5-Land is a better spatial resolution version of the ERA5 climate reanalysis (0.1º×0.1º). The model used in the analysis of ERA5-Land is the shared ECMWF chart for surface changes over land that includes land surface hydrology (H-TESSEL). ERA5-Land data is the most recent so-called second-generation re-analysis dataset, along with the MERRA-2 re-analysis dataset produced by NASA. The spatial resolution of the MERRA-2 dataset is 0.5^0x0.625^0. Therefore, the ERA5-Land re-analysis dataset between 1950-2023 with much higher spatial resolution was used in this project.

Climate projection data

The Max Plank Meteorology Institute Global Model (MPI-ESM-MR) data were used to study future climate changes. MPI-ESM-MR is a new generation Earth System Model (ESMEarth System Model) developed using the European Central Hamburg Model (ECHAM5) atmosphere model and the MPIOM ocean general circulation models. To obtain higher resolution climatic variables from low-resolution global model data, dynamic downscaling was performed with RegCM4.3.4 Regional Climate Model and Nesting (Nested Simulations) method in 130x180 grid matrix with 20 km resolution, for the years 2016-2098 according to the 1971-2000 reference period, temperature and precipitation projections were produced. Daily Mean Air Temperature (°C), Minimum Air Temperature (°C), Maximum Air Temperature (°C), and Total Precipitation (mm) for the period: 1971-2000 (reference), 2024-2098 (future period) were used for the RCP4.5 and RCP8.5 scenarios of the IPCC.

Methodology

Calculation of Emberger Index

Emberger's Pluviothermic Quotient (Q) was used to determine the Mediterranean bioclimatic layers of the study area. Emberger (1930, 1932) elaborated a synthetic expression for the Mediterranean climate by classifying this climate on the base of three important climatic parameters: precipitation, temperature, and evaporation. The precipitation (P) is represented by the annual precipitation (mm). Emberger used this index to classify phytoclimatological (the relationship between climate and plant distribution) regions. Therefore, some scientists have investigated the spread of vegetation according to the Emberger index (e.g., Gavilán, 2005; Savo et al., 2012).

The Emberger's Pluviothermic Quotient (Bio-Climate) is calculated as follows:

$$Q_E = (1000 \times P) / [0.5 \times (M + m) \times (M - m)] = (2000 \times P) / (M^2 - m^2) \quad (1)$$

P = average annual precipitation total in mm,

M = average maximum air temperature of the hottest month expressed in K

m = average minimum air temperature of the coldest month expressed in K.

$$K = 273 + {}^{o}C \quad (2)$$

Mediterranean bioclimate layers are determined according to the classifications given in Table 1 with the results of the precipitation-temperature parameter (*Q*) value obtained by Equation (1).

Classification of phenological stages of the olive tree

Table 2 was created using the olive tree phenology map of the TMS. Future climatic conditions were investigated according to the olive tree phenological stages with the RCP4.5 and RCP8.5 scenarios. While examining the climatic conditions in the phenological stages, we also focused on the extreme climatic impact drivers including durations of the longest dry and rainy days, precipitation amounts of extreme rainy days, and maximum and minimum values of maximum air temperature, etc. were focused on.

In Table 3, the suitability values of the areas suitable for olive cultivation are given according to the main climate criterion. Variable selection and threshold values in Table 3 were compiled by Tuğaç & Sefer (2021), considering phenological periods, expert opinion, and literature information. In this study, threshold values used for determining suitable areas were modified as shown in Table 3. The medium-suitable areas according to January mean air temperature and annual air temperature were partially included in the areas suitable for olive cultivation.

The synthetic or synthesis maps of the areas suitable for olive cultivation were prepared according to the five conformity classes given in Table 3. If precipitation (constant) is suitable, other eligibility indicators will be evaluated in the following order:

- Absolute minimum air temperature in January
- January mean air temperature
- May mean air temperature
- Annual mean air temperature

In addition to precipitation, if two out of four limit conditions of the conformity classes given above were met, the related area was labelled as "suitable" for olive cultivation for the considered RCP scenario and the study period. The annual average precipitation total among the selected climatic impact drivers is the key variable here. Although other conformity classes are suitable, when the annual average total precipitation values are below the limit value, the relevant area is considered "unsuitable" for olive cultivation.

Table 1. Modified classification of the Pluviothermic Quotient (Bio-Climate) and associated biomes/ecosystem suggested for the Mediterranean Region of Türkiye (rearranged for the North Aegean Sub-region of the Western Anatolia based on Özcan et al. (2018).

Biome/Ecosystem	Modified Emberger's Q_E	Emberger's Bio-Climate Types
Humid temperate and subtropical forests (mostly coniferous)	$100 < Q_E$	Humid
Semi humid subtropical and mid-latitude coniferous, mix forests and maquis (macchia)	$75 < Q_E < 100$	Semi humid
Semi humid subtropical and mix forests and maquis	$63 < Q_E < 75$	Moist-sub humid
Dry subtropical and mid-latitude deciduous forests and bush or maquis	$50 < Q_E < 63$	Dry-sub humid
Step, grassland, and short-tall bushes	$30 < Q_E < 50$	Semiarid

Table 2. Olive Tree Phenological Stages developed for the North Aegean Sub-region by using the existing phenological observations.

Period	Phase	Time interval
Before the vegetation period	Precipitation	October – December
	Dormancy	December – January
Vegetation period	Swelling	February – April
	Blooming	16 May – 15 June
	Fruit formation	1 June – 15 July
	Ripening and harvest	16 October – 15 December

Table 3. Agricultural climate conformity classes and limit values of variables (Sys, 1993; Shalaby, 2006; Guo, 2010; Brito, 2019, Tuğaç & Sefer, 2021)

Sub Criterion	Unit	Conformity classes and values				Threshold values for suitability map
		Suitable	Medium-suitable	Less suitable	Not suitable	
Main Criterion: Climate						
Annual mean air temperature	°C	20 – 15	15 – 14	14 – 13	< 13	14 – 20
Absolute minimum air temperature in January	°C	2 – (-4)	-4 – (-6) 2 – 4	-6 – (-7.5) 4 – 6	< -7.5 > 6	2 – (-4)
January mean air temperature	°C	6 – 10.5	10.5 – 12 6 – 5	12 – 13 5 – 4	> 13 < 4	5 – 10.5
May mean temperature	°C	18 – 23	23 – 26 18 – 17	26 – 30 17 – 16	> 30 < 16	18 – 23
Annual precipitation total	mm	600 – 1100	600 – 400 1100 – 1200	400 – 300 1200 –1400	< 300 > 1400	600 – 1100

Results

Present Land Cover and Association with Major Geomorphological Units

Based on the CLC2018 database we originally prepared Figure 2 presenting geographical distribution of the prominent districts and sub-regions of dense olive grove lands in Türkiye. These districts and sub-regions, which are clearly seen on the CLC map or defined based on the geographical distribution of large and dense olive groves, show a distinct spatial clustering. With respect to ecological geography of the olive groves shown in Figure 2, our study area takes place mainly in the coastal Balıkesir district and partly in the northwest of the Manisa district of the North Aegean Sub-region of Türkiye (Figure 3a).

Olive and Olive Oil Production in The Study Area

Balıkesir and Manisa are among the most important olive and olive oil producing provinces, in Türkiye. In Figure 3, the number of olive trees in the last 11 years, obtained in the last 10 production seasons, and estimated to be obtained in the 2021-2022 production season, the olive production reserved for table olives and olive oil, and the estimated olive oil production amounts (tons) are given for Balıkesir and Manisa provinces, respectively. In the last 5-6 years, there has been an increase in the production of olive trees, and olive and olive oil in general in these two provinces (Figure 2). These statistics were compiled within the scope of olive oil product yield determination studies by official assignment of the General Directorate of Plant Production of the Republic of Türkiye Ministry of Agriculture and Forestry, under the coordination of the National Olive and Olive oil Council (NOOC, 2021). The "National Official Determination Committee of Olive and Olive Oil Harvest" determines production of table olives and olive oil for the 2021-2022 production season in all olive growing districts and regions.

Evaluation of Present Olive Grove Lands Concerning Major Geomorphological Units

Geographically, the olive groves in the study area are mainly grown on 'agro-ecologic' geomorphological units (landforms) such as low-lying plateaus and hilly lands, relatively small slope deposits or alluvial cones with unsorted mixed coarse material with low/medium slope, wider alluvial fans with low slope, and fluvial terraces at various elevation levels, and on the geomorphological units similar to piedmont, which are formed by the combination of alluvial fans developed side by side, and, to a lesser extent, coarse material accumulation cones and alluvial cones (Figure 1a) (Photo 1).

This relatively large combined alluvial fans like piedmont, are largest in front of the slopes of the Mount Ida and the Madra Mountain - Kozak Plateau (i.e., geologically a plutonic originated granite massif - granitoid) (MTA, 2022) facing the Bay of Edremit (Figure 1a). It is known that olive cultivation was traditionally grown on such geomorphological units in the past. In recent years, olive cultivation has been carried out in the alluvial flood plains such as in the Bakırçay valley and Akhisar – Saruhanlı plains, where tobacco and cotton were cultivated widely until 30-40 years ago, and on the lowest terraces immediately surrounding the current floodplain.

The geomorphological units where olive groves are grown in the largest areas over the study area are the low-sloping alluvial plains similar to the piedmont plain, which are mainly formed by the combination of the alluvial fans and cones located in the front parts of Mount Ida, Madra Mountain and the high Kozak plateau overlooking the Edremit Gulf (Figure 1a). These alluvial geomorphology-origin landforms were highly fragmented by streams at the mid to late Miocene, the Pliocene and Pleistocene epochs during the geomorphological evolution of the north-west Anatolia throughout the Upper Tertiary period and turned into low plateaus and hills in some places. Low-lying plateaus and low hilly landforms located between Ayvalık and Burhaniye in the Northern Aegean coastal zone can be added to these geomorphological units (Figure 1a).

In addition to these, the geomorphological units where olive groves cover large areas are low plateaus, terraces and alluvial cones or fans located in the north and east of the Bakırçay River delta and generally in the south and east parts of the Soma and Kırkağaç plains (Figure 1a). Apart from the large olive plantations surrounding the Bay of Edremit, the other largest olive plantations in the study area are distributed in the alluvial flood plains of Saruhanlı and Akhisar plains in the south-east of the study area and on the alluvial fans and fluvial terraces (Figure 1a).

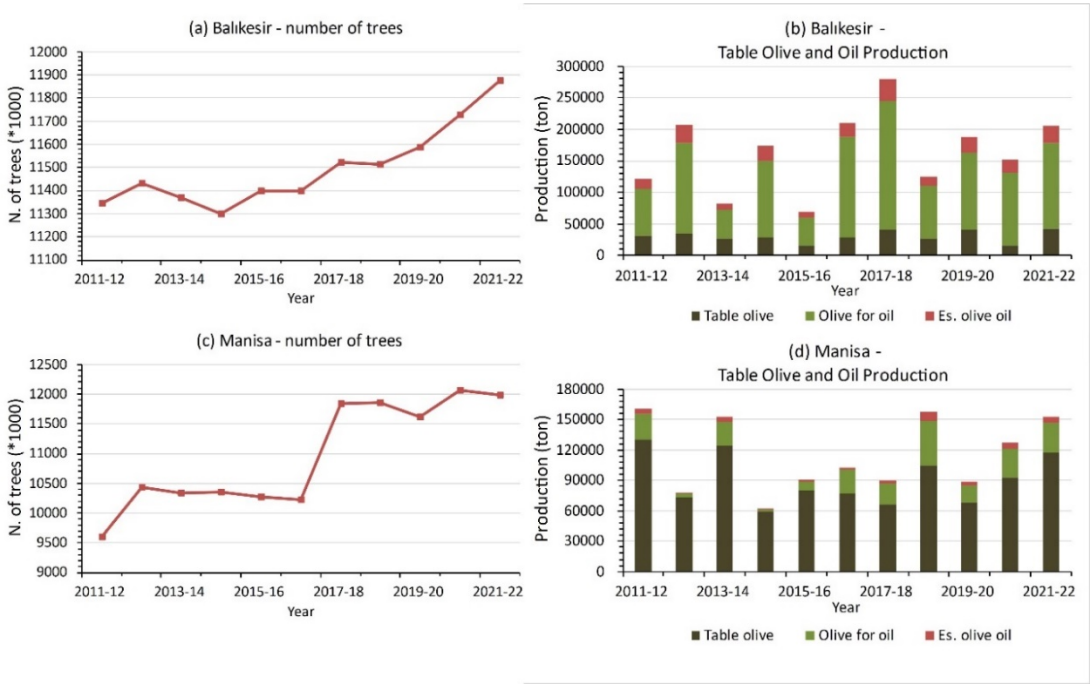

Figure 3. The number of olive trees obtained in the last 10 production seasons and estimated to be obtained in the 2021-2022 production season, the olive production allocated for table olives and olive oil, and the estimated olive oil production amounts for (ab) Balıkesir and (cd) Manisa provinces.

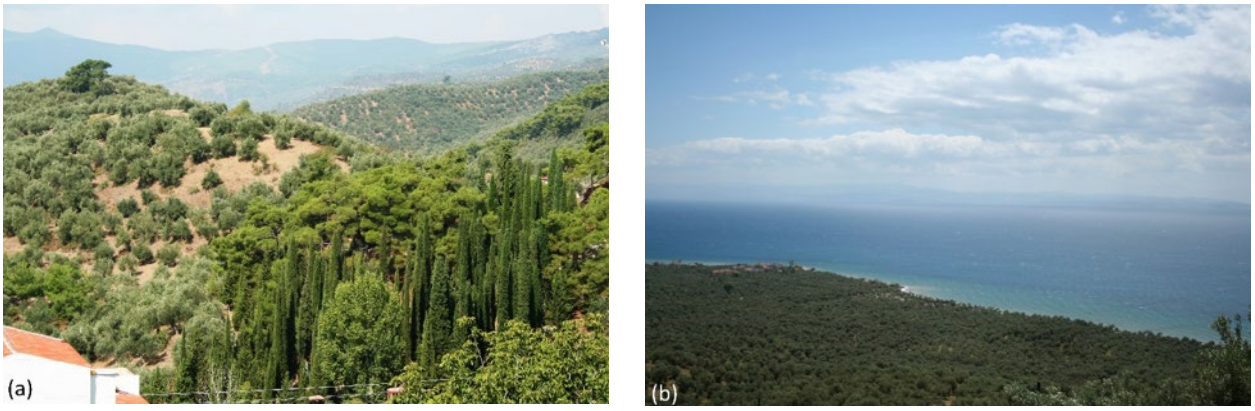

Photo 1. Some examples of the Mediterranean ecogeography from the southern part of the Kaz Mountain exposed to the Edremit Bay (a) An ecogeography including pistachio pine (*Pinus pinea*), red or Turkish pine (*Pinus brutia* Ten) and the Mediterranean tall cypress (*Supressus sempervirens* var *pyramidalis*) and olive groves in the historical Nusratlı Village, which was established on a low plateau and hilly geomorphological landscape on the southern skirts of Kaz Mountain overlooking the Edremit Bay; (b) Dense olive groves grown on the geomorphological unit of an alluvial fan extending to the sea, near the district of Altınoluk town, on the southern skirts of Kaz Mountain overlooking the Edremit Bay.

On the other hand, although it is not clearly visible on the CLC2018 map, on the edges of the alluvial flood plain of the Bakırçay River, which is also a tectonic-origin depression, that is, a graben, like the Edremit Gulf, a wide area extending from the Çandarlı (Bakırçay) delta to the tectonic-origin Soma plain, which is the largest plain at the end of the Bakırçay valley, there are olive groves with a somewhat scattered distribution. In addition, olive groves take up large areas in the eastern and southeastern parts of the Greek island of Lesvos facing Türkiye (Figure 1a).

Other Present Land Cover Characteristics

Except for the olive groves, in the remaining part of the study area, forest ecosystems consisting of broad-leaved, coniferous, and broad-leaved/coniferous mixed trees and stands, as well as vineyards, orchards, and annual agricultural products such as vegetables and grains, some of which are also permanently irrigated as in the Bakırçay valley, are distributed (Figure 1b). Mediterranean stone pine (*Pinus pinea* L.), the largest agro-forestry product in the study area, is grown in private and state-owned plantations on the Kozak Plateau (Figure 1b). In the study area, the largest and most densely native/naturalized and managed pure (broad-leaved and/or coniferous) and broad-leaved/coniferous mixed Mediterranean and mid-latitude (paleo boreal relicts) mountain forest biotopes are distributed in the Mount Ida (Türkeş, 2021; Türkeş et al., 2023), and pure and mixed Mediterranean forest ecosystems are distributed in the Madra Mountain - Kozak Plateau ecoregion (Figure 1b).

Present Climatology of The Study Area

Winter season

In Figure 4, the contour lines show the total precipitation variability (mm/month), the vectors and the vector colors show average wind speed (m/s) and mean air

temperature (°C), respectively. Since the effect of friction is significant in winds blowing 10 meters high, these winds are boundary layer gradient winds, not true geostrophic or gradient winds. While examining the seasonal climate of the study area, mid-season months and seasonal average maps were used.

The air temperature of the mountainous areas of Kozak plateau and Kınık district, where the altitude is high, is below 4°C. In winter, the land is colder, and the sea is cooler and warmer than the land, so the winds blow from the land to the sea. Figure 4a shows this clearly. As seen in Figure 4a and 4b, the air temperature is 4-5°C higher in the coastal areas both in January and in winter. Total precipitation reaches its highest value towards Mount Ida and in the gulf region. In general, the total precipitation is higher in the coastal areas and the precipitation decreases significantly towards the continental interior. In Figure 4a and 4b, the effect of orography on precipitation distribution according to the total precipitation pattern is clearly seen.

Spring season

The spatial relationships of air masses and frontal mid-latitude cyclones in western Türkiye (especially the Aegean region) have effects on spring precipitation variability (Türkeş et al., 2009). While mid-latitude cyclones are active in the Aegean and Marmara regions in spring, their effect decreases towards the Mediterranean region.

As seen in Figure 4c, due to the decrease in the temperature difference between the seas and the land, much lighter winds blow over the study area compared to January. It is noteworthy that the air temperature is higher than the surrounding area in the low-altitude flat area between Kozak plateau and Kınık district. This region is like the bottom of a somewhat depression surrounded by mountains, and the precipitation of convective instability is also seen here. In Figure 4d, this situation is clearly seen in the total precipitation patterns in both April and spring.

Summer season

The most blowing local scale wind in the Aegean region, especially in İzmir and Aydın, is the wind coming from the west (İmbat or Günbat in Turkish). This breeze starts to blow in the hottest hours of the day in the afternoon and continues gently until late at night. Since the İmbat wind (cool Aegean summer sea breeze) is cool and humid, it provides the transfer of moist and warm air masses to the interior as well as its cooling effect in summer. However, as can be seen in Figure 4e, due to the large-scale pressure and wind pattern that is effective in summer in the region (from the Azores high pressure to the Monsoon low pressure area), a very strong north-eastern summer breeze blow. Such winds are generally seen in the Eastern Mediterranean sub-region in summer in Türkiye (Türkeş, 2022).

A wind from relatively colder seas to warmer land and therefore an effective moisture transport from the sea to the land is not observed in the region. Therefore, it can be interpreted that the humidity rate is relatively lower than the southern districts (İzmir, etc.) close to the study area.

As seen in Figure 5f, very low summer precipitation, which is typical of the Mediterranean climate, is seen in the total precipitation map of the study region. In general, as in other seasons, the northeast of the study area is colder. This temperature difference appears to be around 5-6°C.

Autumn season

Figure 4g shows the map of total precipitation (mm/month), average temperature (°C) and average wind (m/s) for the mid-autumn month and autumn season. Considering the temperature distribution, the difference between the relatively cold northeastern parts of the study area and the relatively warm southwestern parts is around 3°C.

In Figure 4g, it is seen that a relatively low-strength northerly wind blows very regularly according to the average wind distribution pattern. The effect of orography on the precipitation distribution in the winter season (see Figure 4b) is also seen in the autumn season. Similarly, the coastal areas receive higher precipitation, and this situation continues to decrease towards the continental interior areas where the altitude is low. In terms of wind force, the least strong winds blow in this season after the spring season. In terms of total precipitation, the region generally has higher precipitation in autumn than in spring, and lower precipitation than in winter.

Present and Future Areas Suitable for Olive Cultivation

The following vegetation classification by the International Geosphere–Biosphere Programme (IGBP) shown in Figure 5 is derived from the Terra and Aqua combined Moderate Resolution Imaging Spectroradiometer (MODIS) Land Cover Climate Modeling Grid (CMG) (MCD12C1) Version 6 data product (Friedl and Menashe, 2020).

In Figure 5, the vegetation types of the study area are classified according to IGBP. The green areas labelled with the number 18 represent the current olive cultivation areas. This map will be used to evaluate the future suitability of olive production areas. The results show that future suitable areas according to modified thresholds (Figure 14) are in very good agreement with the present olive cultivation areas as shown in Figure 5. This resemblance with present olive cultivation areas and determined suitable areas with modified thresholds is the key factor for accurate evaluation of future changes in olive cultivation areas.

Analysis of Selected Climate Impact Drivers According to the Phenological Stages and RCP Scenarios

Precipitation conditions

In Figure 6, seasonal annual total precipitation amounts according to the reference period are shown. Although it is not regular according to the RCP8.5 scenario, there is a decrease in seasonal total precipitation in general over the years. According to the RCP4.5 scenario, there is an increase in spring and autumn precipitation in the last quarter of the century and an increase in winter precipitation in the middle quarter of a century. Since winter precipitation constitutes the most important part of the annual total precipitation in the study area, the decrease or increase in precipitation is very important in this period. Therefore, in Figure 7, the spatial distribution of winter precipitation according to the RCP scenarios has been specifically examined.

In Figure 7, the spatial variation of the winter precipitation totals calculated according to the working periods of the RCP scenarios is shown. Total precipitation varies greatly in the study area. Therefore, it is not preferred to show the precipitation changes as a percentage in Figure 7, because changes in quantity will not be seen and the distinction between coastal and terrestrial sections will not be discernible.

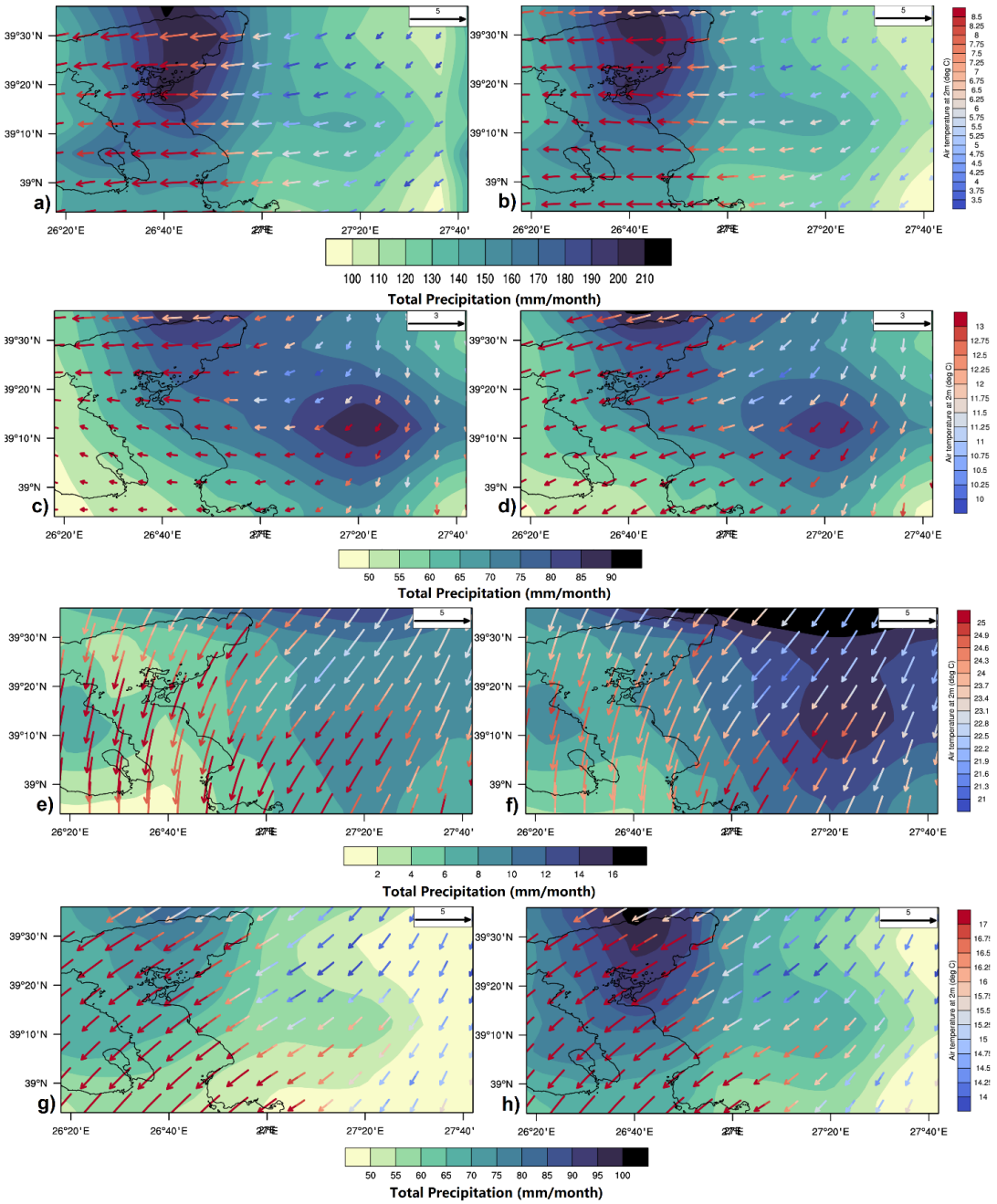

Figure 4. Geographical distribution patterns of average precipitation total (mm), mean air temperature (°C) and average wind velocity (m/s) in the North Aegean Sub-region for the period of 1950-2023 a) January, b) winter season, c) April, d) spring season, e) July, f) summer season, g) October and h) autumn season.

First, when looking at the areal distribution map of winter precipitation calculated with current data for the study region (Figure 4a and 4b), it is seen that the coastal regions receive more precipitation than the continental interior. According to the RCP4.5 scenario, the increase in winter precipitation compared to the 2049-2073 period is seen, and, according to the RCP4.5 scenario, there is an increase in precipitation compared to the inner parts, with the coastal areas being slightly higher for the 2049-2073 period (Figure 7). Decrease in precipitation towards the continental interior, especially the coastal areas, decreases according to both scenarios and for all other periods. The significant decrease seen in coastal areas shows its effect towards terrestrial interior areas in the RCP8.5 scenario 2074-2098 period. However, an increase in precipitation is observed in all RCP8.5 periods, albeit very slightly, in the innermost continental parts.

In Figure 8, the longest dry and rainy periods for the swelling, flowering, maturation, and harvest phases are calculated for the years 2024-2048, 2049-2073 and 2074-2098, according to the reference period. Here, the longest dry period represents the days without precipitation and the longest precipitation variable represents the longest period with precipitation. According to the RPC scenarios, the longest dry period during the flowering phase changes by 2-3 days at most. RCP4.5 scenario shows a decrease in the dry period for the years 2049-2073 during the maturation period. In addition, a significant increase is observed in the swelling period between RCP8.5 (2074-2098). As can be seen in Figure 7, according to the RCP 8.5 scenario, there is a serious decrease in total precipitation between 2074 and 2098. In Figure 8, the longest rainy days do not show any significant change except for the post-2050 RCP8.5 scenario.

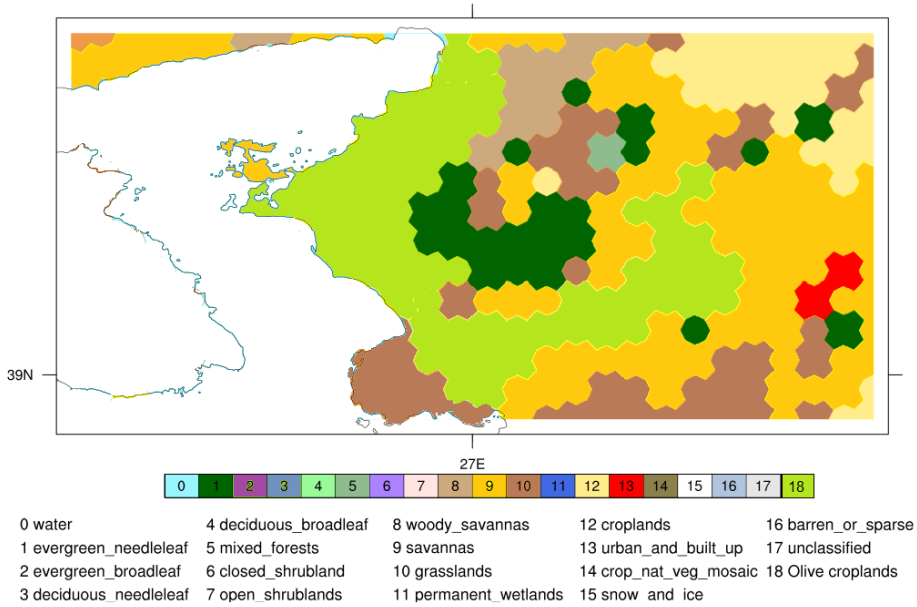

Figure 5. Geographical distribution pattern of the vegetation types of the study area according to the (IGBP) (MCD12C1, https://doi.org/10.5067/MODIS/MCD12C1.006)

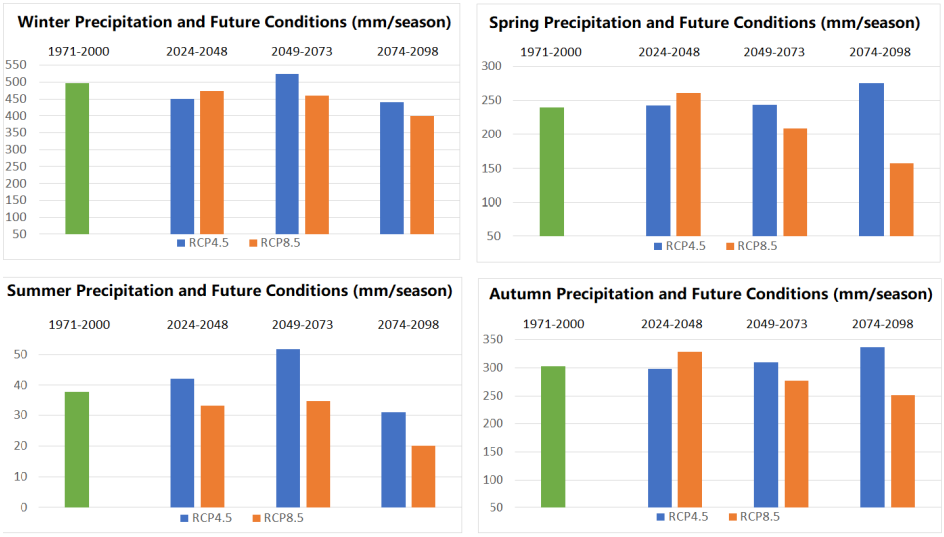

Figure 6. Projected changes in seasonal total precipitation amounts (mm) of the North Aegean Sub-region under two RCP scenarios for three future periods (2024-2048, 2049-2073 and 2074-2098) in comparison with the reference period (1971-2000).

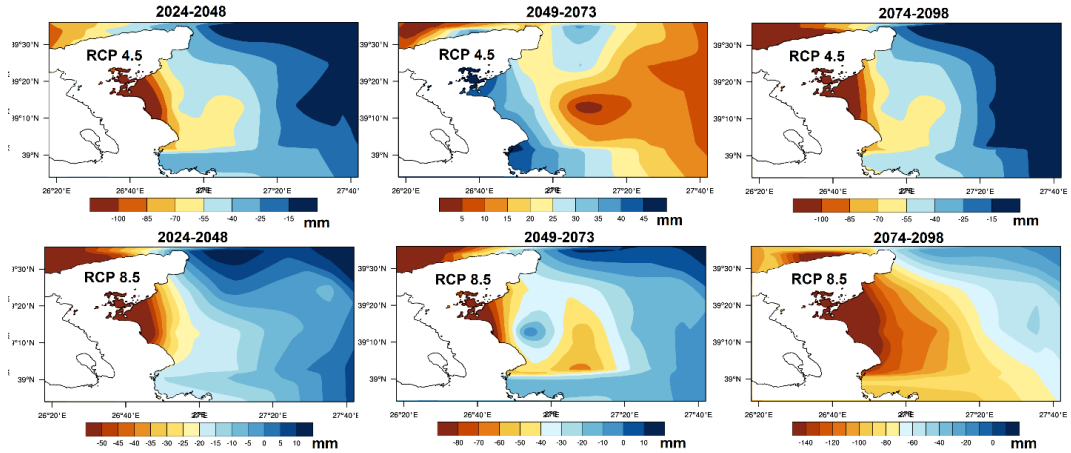

Figure 7. Changes in winter season total precipitation amounts (mm) of the North Aegean Sub-region under two RCP scenarios for three future periods (2024-2048, 2049-2073 and 2074-2098).

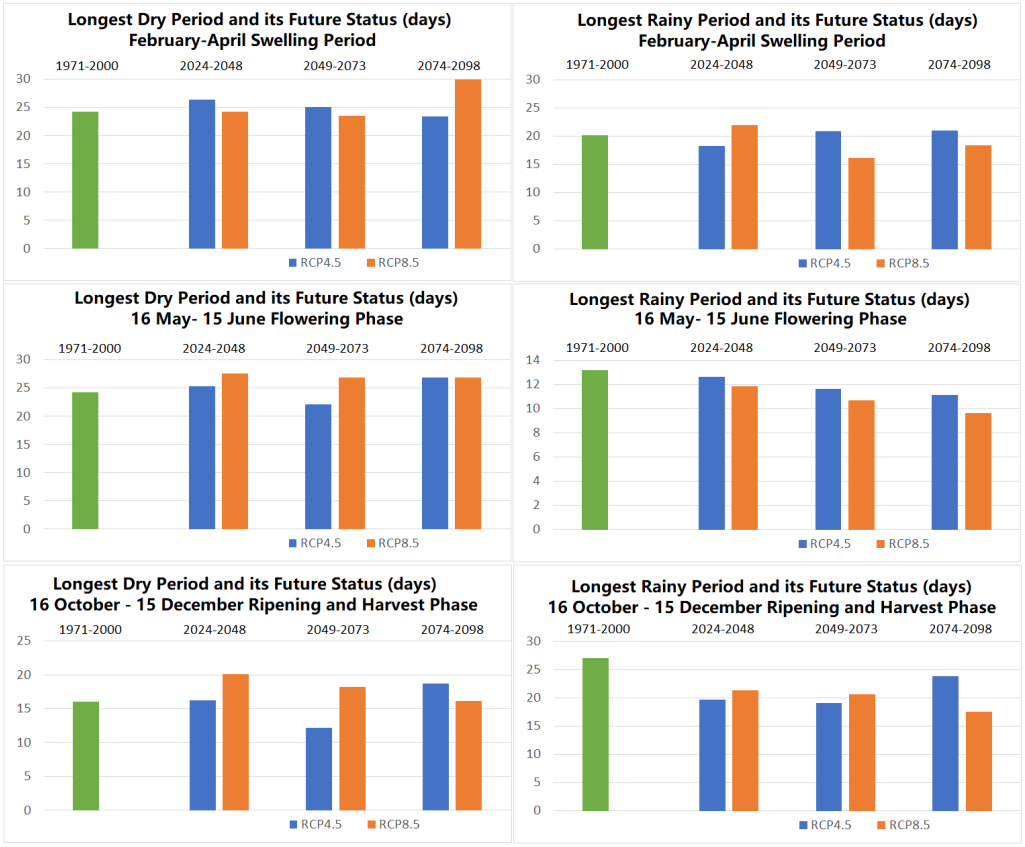

Figure 8. Projected changes of longest dry and wet periods (days) in three phenological stages of olive tree for the North Aegean Sub-region under two RCP scenarios for three future periods (2024-2048, 2049-2073 and 2074-2098) in comparison with the reference period (1971-2000).

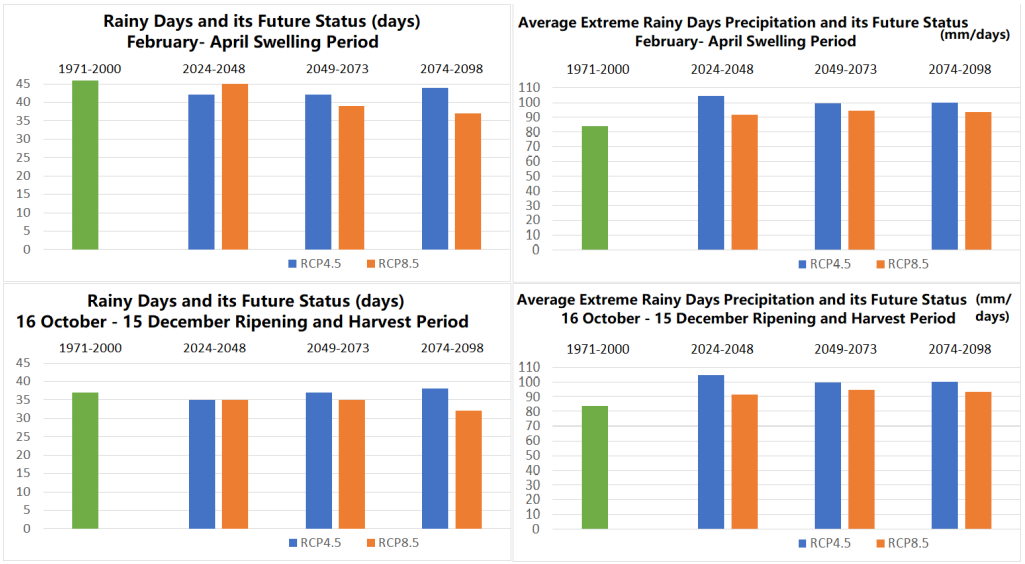

Figure 9. Projected changes in rainy days and precipitation amounts of extreme rainy days in two phenological stages of olive tree for the North Aegean Sub-region under two RCP scenarios for three future periods (2024-2048, 2049-2073 and 2074-2098) in comparison with the reference period (1971-2000).

Especially according to the RCP8.5 (2049-2073) scenario, the longest rainy days decrease by 10 days. Longer rainy days delay the harvest, lower the polyphenols, and decrease the amount of swelling and pollination (EBRD project report, 2023). Expected rainy days in the future according to the reference period are given in both days and amount (mm) (Figure 9). Although there is a slight decrease in the rainy days according to both scenarios, an increase in the amount of precipitation is observed during the ripening and harvesting phases and the swelling period. However, it is considered that this increase will very slightly affect fruit quality and number of fruits. As predicted by many climate projection models, a decrease in precipitation and an increase in precipitation intensity are expected in the study region in the future.

Expected changes of extreme temperature events in the olive tree swelling period according to the reference period in the future are shown in Figure 10.

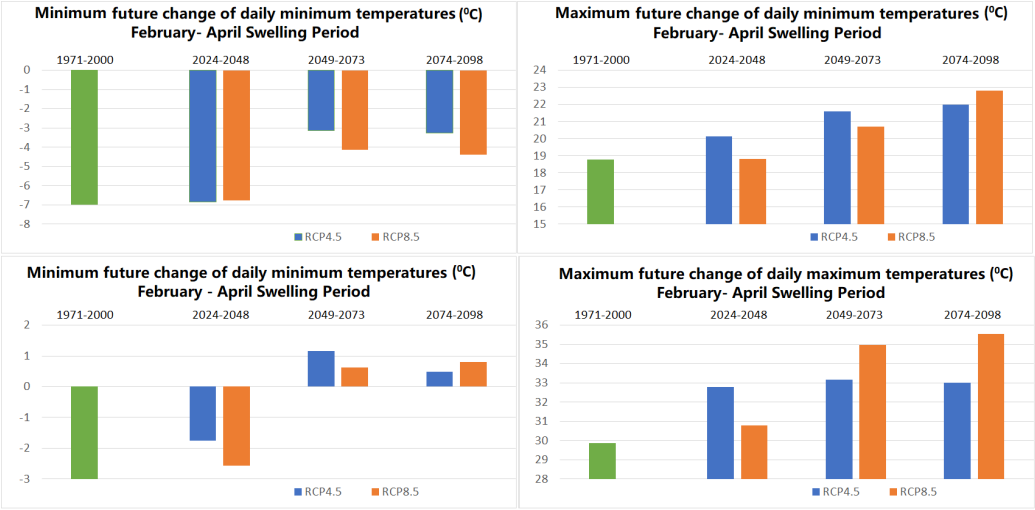

Figure 10. Projected changes in minimum and maximum values of maximum and minimum air temperatures (°C) in the swelling phenological stage of olive tree for the North Aegean Sub-region under two RCP scenarios for three future periods (2024-2048, 2049-2073 and 2074-2098) in comparison with the reference period (1971-2000).

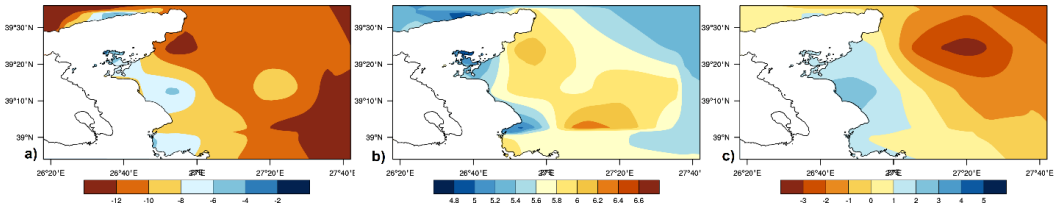

Figure 11. Spatial distribution patterns of projected future climatic changes in the olive tree swelling phase
(a) changes in the longest rainy days according to the RCP8.5 (2049-2073) scenario, (b) changes in the maximum values of the daily maximum air temperatures (°C) according to the RCP8.5 2074-2098 scenario, and (c) changes in the minimum values of daily maximum air temperatures (°C) according to RCP4.5 2049-2073 scenario.

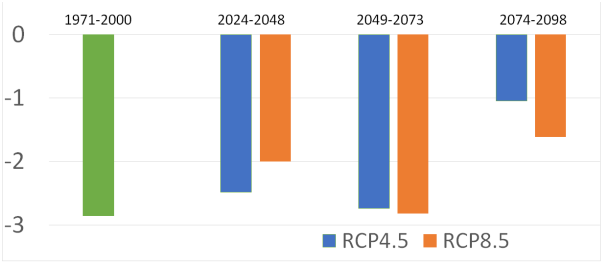

Figure 12. Projected changes in minimum values of minimum air temperatures (°C) in the ripening and harvesting phenological stages of olive tree for the North Aegean Sub-region under two RCP scenarios for three future periods (2024-2048, 2049-2073 and 2074-2098) in comparison with the reference period (1971-2000).

There is an overall increase in the maximum and minimum values of the minimum and maximum temperatures which may cause earlier bloom and increase chilling requirements. Therefore, it can be said that colder extreme weather conditions are not expected in terms of minimum temperatures in the study area. However, at the maximum values of the maximum temperatures, a maximum temperature increases of up to 6°C is observed, especially in the periods after 2050 in the RCP8.5 scenario. The increase in temperature during the swelling period in the study area causes the olive trees to bloom earlier and the growth period to prolong the growth period (Pérez et al., 2008). Therefore, the spatial distribution of this situation will be examined specifically in Figure 11.

While describing the climate of the study region, it was shown that coastal areas receive more precipitation than continental interiors. As seen in Figure 11a, the longest rainy days decrease in coastal areas that receive more precipitation than inland areas. The number of the longest rainy days decreases even more in the interior areas that already receive less precipitation. Therefore, this may increase the effect of possible water stress.

Air temperature conditions

When the graph of minimum of maximum air temperatures is examined, although the reference period is around -3°C on average, positive values appear after the 1950s according to both RCP scenarios. Therefore, this situation is also examined as spatial distribution in Figure 11b, which shows the variation of the maximum values of the daily maximum temperatures in the area.

Especially, the least temperature increase is seen in the coastal areas. It can be said that the increase in temperature is partially seen in higher areas where olive cultivation is mostly done. For this reason, it is seen that the olive trees in the interior areas far from the coast will be more affected by the temperature increase in the swelling stages compared to the coastal areas.

As can be seen, where the climate of the study area is explained, the temperature of the study area is colder in the northeastern part and the air warms up towards the southwest. According to the map of the minimum of the maximum temperature in Figure 11c, the air gets colder in the relatively cold regions, while the warmer coastal and south-southeastern parts are warming. However, it is thought that this situation will not pose a problem for the olive tree during the swelling period.

According to the minimum values of the ripening and harvesting period minimum temperatures given in Figure 12, there is a warming according to both RCP scenarios.

Especially in the last quarter century, an average of 1.5-2°C warming is predicted according to both scenarios. Since the coldness that the olive tree can withstand is around -7 degrees, this predicted increase in minimum temperatures can be viewed positively in terms of olive agriculture.

Determination of Current and Future Bioclimate Layers of the Study Area According to the Emberger Bioclimate Classification

Figure 13 shows the Mediterranean bioclimate layers calculated for the study area according to the Emberger index. The dashed red line in Figure 13 indicates the threshold value modified for this study. According to today's climatic conditions (1950-2023), the northern coastal zones of the study area are rainy and almost all the remaining areas are classified as the Mediterranean bioclimate with low precipitation. According to the RCP4.5 scenario, there is no significant change in the Mediterranean bioclimate type of the study area. There is a decrease in rainy areas in the northeast of the study area and a slight increase in semi-arid areas in the southwest (Figure 13). According to the RCP8.5 scenario, similar changes are seen in the RCP4.5 scenarios in the first quarter-century period. However, in the middle quarter period (2049-2073), there is a significant increase in semi-arid areas from the eastern and southeastern regions to the western parts, although the rainy Mediterranean bioclimate is almost absent (Figure 13).

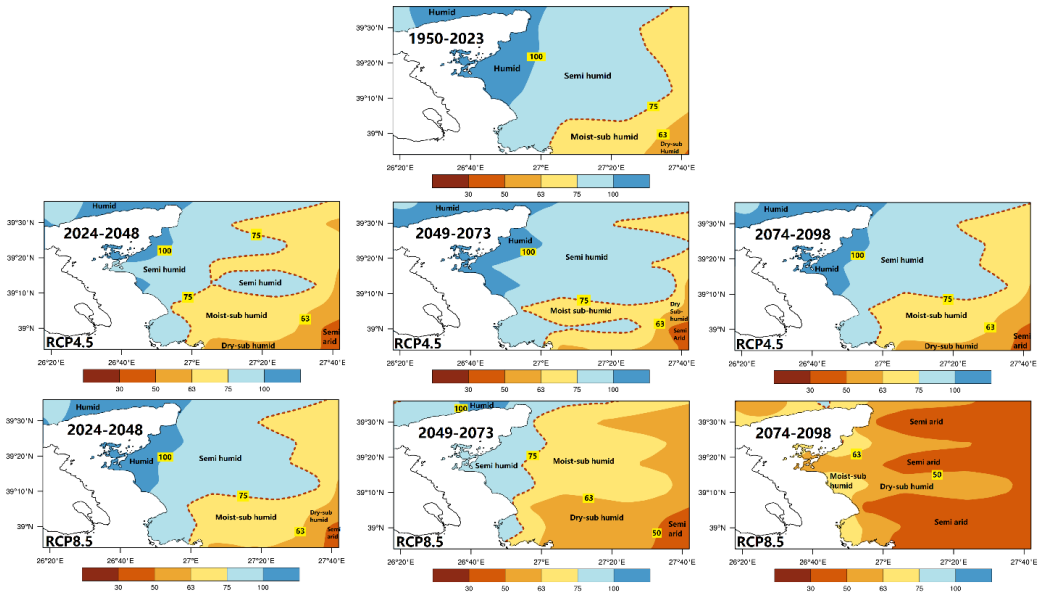

Figure 13. Geographical distribution patterns of the present and future Mediterranean bioclimate classes of the North Aegean Sub-region according to the Emberger Bioclimate Classification.

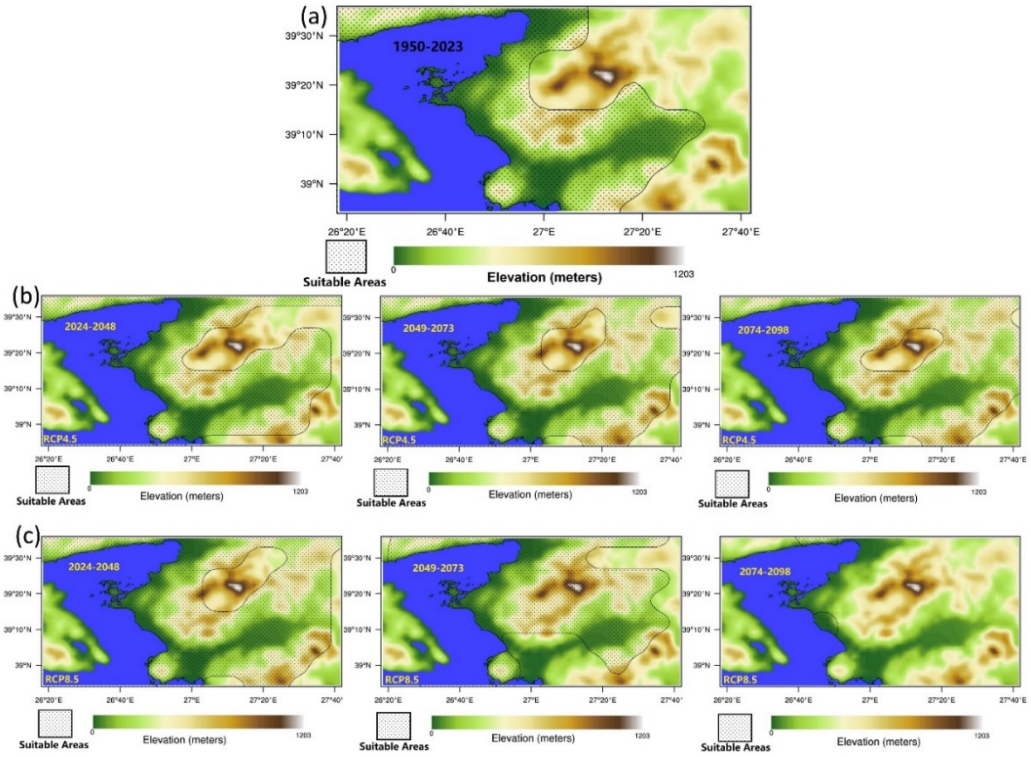

Figure 14. Geographical distribution patterns of (a) present suitable areas for olive cultivation, and future changes in the suitable areas for olive cultivation according to five conformity classes for the periods of 2024-2048, 2049-2073 and 2074-2098 under (b) the RCP 4.5 and (c) RCP8.5 scenarios.

This increase reached up to the last quarter-century variable (2074-2098) coastal areas, and even the entire study area was determined as the semi-arid Mediterranean bioclimate layer, except for some coastal areas. In arid conditions, olive trees can stop crown growth and build drought resistance by reducing photosynthesis and transpiration. However, water stress during the growth periods negatively affects production and development, causing significant changes in fruit quality, maturity, and oil content (Ayaz and Varol, 2015). For this reason, water stress, which is likely to occur after 2050 in much warmer and semi-arid climatic conditions than today, should be examined in detail and precautions should be taken against it, according to the RCP8.5 scenario.

Figure 14a is the synthesis map of the present and predicted future conditions of the areas suitable for olive cultivation calculated with the proposed methodology in this project. Dashed areas in Figure 14a indicate "suitable", and the other areas show "unsuitable" fields for oil cultivation. The suitable areas in Figure 14a consist of low-lying plateaus and low hilly landforms and low-sloping alluvial plains. The unsuitable areas are mostly relatively colder areas like high plateaus and mountainous regions. The areas suitable for oil cultivation determined with the methodology proposed in this project are very similar to the present oil cultivation areas shown in Figure 5. This shows that the proposed methodology and the selected conformity classes are very appropriate for determining areas suitable for olive cultivation for the study area. In addition, determining future changes according to present conditions (1950-2023) will be significant because of the consistency of the results in Figure 14a.

Figures 14b and 14c clearly depict the expected future changes in suitable olive cultivation areas according to study periods for RCP 4.5 and RCP8.5 scenario, respectively. The areas suitable for olive cultivation (dashed areas) increased according to present conditions due to slightly decreased average annual total precipitation and projected warming in temperature variables in relatively colder (mountainous) areas. Altitude is one of the restriction factors for olive growing. For example, 900-1200 meters is a border for the Mediterranean region. Therefore, the expansion of the suitable areas for olive cultivation won't be affected by the increased altitude in the suitable areas in Figure 14b-c. The suitable areas slightly change with the study period. This result is in scope with the results in Figure 13 showing the change in Mediterranean climate classes.

Because of the slightly increased average annual total precipitation for the period 2024-2048 RCP8.5 scenario and expected warming in temperature variables in high altitudes, the study area becomes much more suitable for olive cultivation as seen in Figure 14c. However, the expected decrease in average total precipitation and relatively higher warming in temperature variables for the period 2049-2073 resulted in a decrease of the suitable olive cultivation areas. Nevertheless, suitable olive cultivation areas increased for the period 2049-2073 according to present conditions. As seen in Figure 6 the total precipitation significantly decreases for the period 2074-2098. Also as shown in Figure 13, the Mediterranean climate of the study area becomes mostly semi-arid according to Emberger climate classification for the period 2074-2098. Therefore, there is no suitable area left for olive cultivation in almost all the study area for the RCP8.5 (2074-2098) scenario (Figure 14c). It must be noted that the unsuitable areas for olive cultivation are in good agreement with areas classified as semi-arid according to Emberger bioclimatic classes.

Conclusions

This study is aim at investigating future changes in sustainability of olive farming by means of selected climatic impact drivers and a bioclimatic index, and the climatic suitableness variables and various specific indicators including phenology related to olive tree cultivation compared with present conditions in the North Aegean sub-region of Türkiye mainly characterised with dry and hot summer subtropical Mediterranean macro climate.

Generally, there are no significant differences observed between RCP4.5 and RCP8.5 in terms of warming trends in air temperatures in the 2024-2048 period. However, according to the RCP8.5 scenario, the warming will increase regularly, and this warming reaches an average of 5-6°C in the far future period of 2073-2098. As expected, the most adverse effect of predicted warming will occur in the last quarter of the century under the RCP8.5 scenario.

Regarding the present climate, the coastal areas in the north of the study area are rainy during the cold months of the year from the November to April, and almost all the remaining areas are classified as Mediterranean bioclimate with low precipitation according to the Emberger Bioclimate Classification. In RCP4.5 scenario, there is no significant change is expected in the Mediterranean bioclimate type of the study area. However, according to the RCP 8.5 scenario, in the middle quarter period (2049-2073), there will be a significant increase in dry-sub humid areas from the east and southeast to the west. This increase will cover up to the coastal areas in the last quarter-century period (2074-2098), and even the entire study area was determined as the dry-sub humid and semi-arid Mediterranean bioclimatic layer, except for some part of Aegean Sea coastal zone.

According to the annual total precipitation projections in the RCP8.5 scenario, it is predicted that the areas suitable for olive production will decrease in the period of 2049-2073, and almost the entire study area will be in the category of medium suitable for olive production in the period of 2073-2098. An increase of about 6°C is expected in the maximum values of the average maximum temperatures during the swelling periods, especially in the periods after 2050, according to the RCP8.5 scenario. The increase in the extreme maximum temperatures in the study area may cause the olive trees to bloom earlier and prolong the growth period (Pérez et al., 2008). Also, by considering the high vernalization requirement of the main olive variety in the study area a 6°C temperature increase might significantly decrease the olive yields and will force farmers to transition to new varieties with relatively low vernalization requirements.

Water stress from decreased precipitation amounts in RCP 8.5 scenario will also very likely cause heat stress due to increased air temperatures and evapotranspiration rates. This stress might physiologically damage olive trees, cause

flower shedding and thus reduce olive yields. Also, of possible water stress and changing temperature and precipitation regimes on olive pests (e.g., olive fly pests) and diseases (e.g., fungal diseases) might be increased and therefore, necessary precautions should be taken, especially after 2050.

As a result, it can be assessed briefly that even though the North Aegean sub-region of Türkiye will be likely more suitable for olive cultivation because of a small increase in annual total precipitation amounts in the period 2024-2048 under the RCP8.5 scenario and expected warming in air temperature drivers in high altitudes, an evident projected decrease in total precipitation amounts and relatively higher warming levels in air temperature drivers in the period 2049-2073 will very likely lead a substantial decrease in the suitable olive cultivation areas. Further, the Mediterranean climate of the study area will very likely face mostly semi-arid environmental conditions according to the Emberger climate classification for the period 2074-2098. Consequently, there would not be a climatically suitable area left for olive cultivation in majority of the study area under the RCP8.5 (2074-2098) scenario conditions.

On the other hand, according to both RCP scenarios, there is a possibility of extension of suitable areas for olive cultivation towards low to mid-elevation plateaus and mid-elevation slopes of mountainous areas and high plateaus particularly facing suitable aspects to lower negative effects of projected warming and dryness. These areas are presently characterized mainly by pure and mixed Mediterranean forest ecosystems consisting of broad-leaved and coniferous mixed trees and stands (Türkeş, 2021; Türkeş et al., 2023). In the future, considering the difficulty of adaptation of present forest ecosystems to changing climate conditions, these areas can be replaced with olive orchards.

Declarations

Ethical Approval Certificate

This article does not contain any studies with human or animal participants performed by any of the authors.

Author Contribution Statement

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Sinan Sahin and Murat Türkeş. All authors commented on previous versions of the manuscript, and all authors read and approved the final manuscript.

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Conflict of Interest

The authors declare no conflict of interest

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The Effect of Different Sulphur Sources Applied at Various Rates on Soil pH

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ABSTRACT

Soil pH, governed by the relative concentrations of hydrogen (H^+) and hydroxyl (OH^-) ions, is a key factor affecting the chemical, physical, and biological properties of soils. Most soils in Türkiye are alkaline due to calcareous parent material and climatic influences, which restricts the availability of essential nutrients to plants. Sulphur applications are widely employed to reduce soil pH and increase nutrient bioavailability. The use of Sulphur for the amelioration of alkaline soils will continue to be a crucial strategy for enhancing agricultural sustainability in the future. This study investigates the effects of different Sulphur sources on the pH of sandy and clay-loam texture soils. This study investigates the effects of different Sulphur sources on the pH of sandy and clay loam textured soils. The soil samples used in the research were taken from Pınarbaşı and Melikgazi districts of Kayseri province, and soil samples were taken from both regions from a depth of 30 cm and from 20 randomly determined different points. Sulphur applications were applied at rates of (0, 0.02, 0.04 g 100 g^{-1}) (X: powdered Sulphur) and (0, 0.044, 0.088 g 100 g^{-1}) (Y: granular Sulphur) based on weight for clay-loam and sandy textured soils, respectively. Samples taken on days 0, 15, 30, 60, 90, 180, and 360 post-applications showed that the impact of Sulphur applications on soil pH change was significant across all treatments ($p<0.01$). The lowest pH measurement, 6.92, was observed in sandy textured soils with an application from granular Sulphur at 0.088 g 100 g^{-1}. The pH change in clay-loam textured soils was found to range from 8.13 to 7.79, and in sandy textured soils from 7.69 to 6.92. These changes suggest that the acidifying effect of Sulphur oxidation on soil pH varies depending on the soil's buffering capacity, particle size ratio, application rate, and incubation day. Consequently, the granular Sulphur was found to be more effective compared to the control and powdered Sulphur , and an application rate of 0.088 g 100 g^{-1} might be effective for both clay-loam and sandy soils. However, due to its lack of economic feasibility, 0.044 g dose or the doses from powdered Sulphur might be more appropriate.

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Introduction

The acidity, neutrality, and alkalinity levels of soil can be expressed through the relative concentrations of hydrogen (H^+) and hydroxyl (OH^-) ions in the soil solution, representing a metric known as the soil pH value (Yaraş and Daşgan, 2012). Soil pH is among the abiotic factors affecting soil characteristics (Rath et al., 2019; Zeng et al., 2019). It significantly influences many chemical, physical, and biological properties of the soil. The effects on the availability, mobility, and activities of microorganisms of plant nutrient elements are critically important for agricultural sustainability. For healthy and high-quality plant growth, soil reaction is generally preferred to be between 6.5 and 7.5 in agricultural cultivation (Güneş and Sönmez, 2018). Turkish soils possess diverse soil characteristics due to the influence of active and passive soil factors (Paton, 2023). Active factors like climate conditions and passive factors such as the limestone and calcareous materials of the bedrock have generally led to an alkaline character in Turkish soils (Kapur et al., 2017). A study of Turkish soils has determined that a total area of 21 579 99 hectares exhibits slightly alkaline characteristics based on soil pH values (Sönmez et al., 2018; Uçgun et al., 2019), with the distribution of soil pH across Türkiye shown in Figure 1 (Sönmez et al., 2018).

Sulphur (S), used in the amelioration of calcareous and highly reactive soils (Karaman et al., 2012; Güneş and Sönmez, 2018), is considered the fourth essential macro-nutrient element following N, P, and K based on its contributions to plant metabolism and growth activities (Tietel et al., 2022). Sulphur is present in the soil in both organic (carbon-bonded S and ester sulfate) and inorganic (sulfate (SO_4^{-2}) and sulfite (SO_2^-)) forms (Awadalla et al., 2007; Abou Hussien et al., 2020). Plants obtain S sources from the atmosphere as SO_2^-, through their leaves via stomata in gas form, and as (SO_4^{-2}) from the soil solution (Zhao et al., 1999; Orman, 2012).

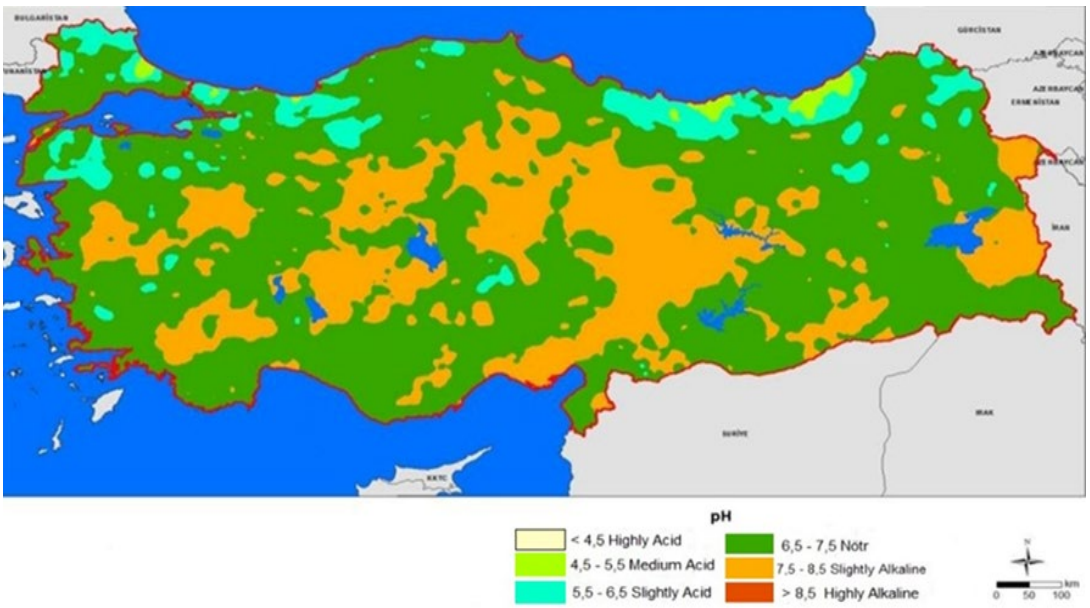

Figure 1. Map illustrating the pH distribution across the soils of Türkiye

Figure 2. Google Earth image of the location where the soil sample was taken in Pınarbaşı district

In agriculture, ammonium sulfate, iron sulfate, and potassium sulfate are among the alternative S-containing fertilizers, with elemental S also being used in agricultural applications and for amelioration purposes (Fahad et al., 2021). Elemental S applications, particularly in soils rich in calcium carbonate and with high pH values, are implemented to improve plant growth and nutrient availability. This method aims to enhance the availability of phosphorus (P) and other micro-nutrients critical to plants by lowering soil acidity (Zhao et al., 2015; Fuentes-Lara et al., 2019).

The current literature contains a limited number of studies examining the interactions of applications in different soil textures over time and according to S doses. The primary objective of this study is to determine the effect of various S sources on pH changes in different soil textures and to identify the most effective S dose.

Materials and Methods

The soil samples used in the study were randomly collected from the coordinates 38°44'12"N, 36°22' 37"E from Pınarbaşı district of Kayseri province and 38°42'53"N, 35°42'33"E from Melikgazi district. It was taken from different points from 0-30 cm soil depth (Figure 2, Figure 3). The research was carried out at Erciyes University Faculty of Agriculture Research Unit. The soil samples taken from the fields were passed through 4 mm sieves and added to 100 gram containers in 3 replicates. The physical and chemical properties of the experimental soil taken from the Pınarbaşı and Melikgazi district are given in Table 1. Soil analyses were conducted using the hydrometer method for particle size analysis (Bouyoucos, 1951), pH, and EC (1:2.5 soil: distilled water) (USSL Staff, 1954).

Figure 3. Google Earth image of the location where the soil sample was taken in Melikgazi district

Table 1. Selected physical and chemical characteristics of the soil sample collected from Pınarbaşı and Melikgazi district

Soil properties	Value	
	Pınarbaşı	Melikgazi
Textural class	Clay loam	Sand
pH (1:2.5)	8.13	7.67
EC (dS m^{-1}) (1:2.5)	0.67	0.21
$CaCO_3$ (%)	11.08	2.6
Organic matter (%)	1.24	0.89
Available P (mg kg^{-1})	13.12	3.11
Extractable Zn (mg kg^{-1})	0.89	0.27
Extractable Fe (mg kg^{-1})	5.49	1.49
Extractable Cu (mg kg^{-1})	0.91	0.64
Extractable Mn (mg kg^{-1})	0.63	0.13

The determination of $CaCO_3$ was performed using the Scheibler calcimeter method (Richards, 1954), organic matter content by the Walkley-Black method (Walkley and Black, 1934), available P by the Olsen method (Olsen and Sommers, 1982), and trace elements by the DTPA (Diethylene triamine penta acetic acid) extraction method (Lindsay and Norvell,1978).

The experiment was designed as a randomized complete block design with three replications. A 100 g soil sample was modified with powdered Sulphur at concentrations of 0 (X0), 0.02 (X1), and 0.04 g (X2), and with granular Sulphur at concentrations of 0 (Y0), 0.044 (Y1), and 0.088 g (Y2). The samples were then brought to field capacity and incubated at 24 °C for 360 days. pH measurements were recorded at the beginning of the experiment and on days 0, 15, 30, 60, 90, 180, and 360. The average results of the study were analysed using JMP 13.2.0 statistical software, and differences between means were determined using Tukey's test at a significance level of $p < 0.005$ (Snedecor and Cochran, 1967).

Results and Discussion

The experimental findings indicated that the two different S sources caused significant alterations in soil pH across all sampling times, soil textures, and application doses ($p<0.01$). Considering all sampling periods and application doses across varied textures, a decrease in average soil pH values was detected compared to the control group. According to all results, the highest soil pH was observed in the control groups, while the lowest pH, recorded at 6.92, was found in sandy textured soil with the Y2 application on the 360th day. The variations in soil pH over the sampling times ranged from 7.67 to 7.53 for the X1 application and 7.69 to 7.21 for the X2 application in sandy textures. For the Y1 application, it ranged from 7.67 to 7.23, and for the Y2 application, from 7.69 to 6.92. In clay textures, for the X1 application, pH ranged from 8.11 to 7.83, for the X2 application from 8.13 to 7.79, for the Y1 application from 8.09 to 7.81, and for the Y2 application from 8.10 to 7.74 (Table 2). The interactions of dose application time are presented in Figure 2. The effects of the applications in sandy textures led to a more pronounced decrease in pH values compared to clay textures. The impact of x S source applications on soil pH in sandy and clay textures is illustrated in Figure 3, and the impact of y S source applications on soil pH in sandy and clay textures is depicted in Figure 4.

The process of elemental S oxidation within the soil environment initiates a cascade of chemical reactions, predominantly the generation of Sulphur ic acid (H_2SO_4), which inherently leads to a decrement in soil pH through its interaction with calcium carbonate ($CaCO_3$) present in the soil, thereby facilitating the formation of calcium sulphate ($CaSO_4$).

Table 2. Temporal average changes in soil pH due to applications of different S sources

Texture	Dose	Period							
		7 th day	15 th day	30 th day	60 th day	90 th day	180 th day	360 th day	Average
Clay loam	X0	8.10^{a}	8.11^{a}	8.11^{a}	8.10^{a}	8.10^{a}	8.10^{a}	8.11^{a}	8.10^{a}
	X1	8.11^{a}	8.11^{a}	8.11^{a}	8.09^{a}	8.05^{a}	7.91^{b}	7.83^{bc}	8.03^{b}
	X2	8.13^{a}	8.13^{a}	8.11^{a}	8.09^{a}	8.03^{ab}	7.88^{bc}	7.79^{c}	8.02^{b}
Clay loam	Y0	8.09^{a}	8.10^{a}	8.09^{a}	8.09^{a}	8.09^{a}	8.09^{a}	8.09^{a}	8.09^{a}
	Y1	8.09^{a}	8.09^{a}	8.07^{a}	8.07^{a}	8.00^{ab}	7.88^{b}	7.81^{bc}	8.00^{b}
	Y2	8.10^{a}	8.09^{a}	8.07^{a}	8.04a^{b}	7.90^{b}	7.82^{bc}	7.74^{c}	7.96^{bc}
Sand	X0	7.68^{c}	7.69^{c}	7.67^{c}	7.67^{c}	7.67^{c}	7.69^{c}	7.68^{c}	7.67^{c}
	X1	7.67^{c}	7.61^{cd}	7.61^{cd}	7.60^{cd}	7.58^{cd}	7.54^{d}	7.53^{d}	7.59^{c}
	X2	7.68^{c}	7.62^{cd}	7.60^{cd}	7.56^{d}	7.29^{f}	7.28^{f}	7.21^{f}	7.46^{cd}
Sand	Y0	7.67^{c}	7.67^{c}	7.66^{c}	7.66^{c}	7.66^{c}	7.68^{c}	7.68^{c}	7.67^{c}
	Y1	7.66^{c}	7.65^{c}	7.64^{c}	7.60^{cd}	7.37^{df}	7.36^{df}	7.23^{f}	7.50^{cd}
	Y2	7.69^{c}	7.66^{c}	7.60^{cd}	7.52^{d}	7.28^{f}	7.20^{f}	6.92^{fg}	7.41^{f}

X1: Application of 0.02 g of from powdered Sulphur to the soil, X2: Application of 0.04 g of from powdered Sulphur to the soil, Y1: Application of 0.044 g of from granular Sulphur to the soil, Y2: Application of 0.088 g of from granular Sulphur to the soil; *: Treatments denoted by the same letter within the same column are not significantly different ($p<0.05$).

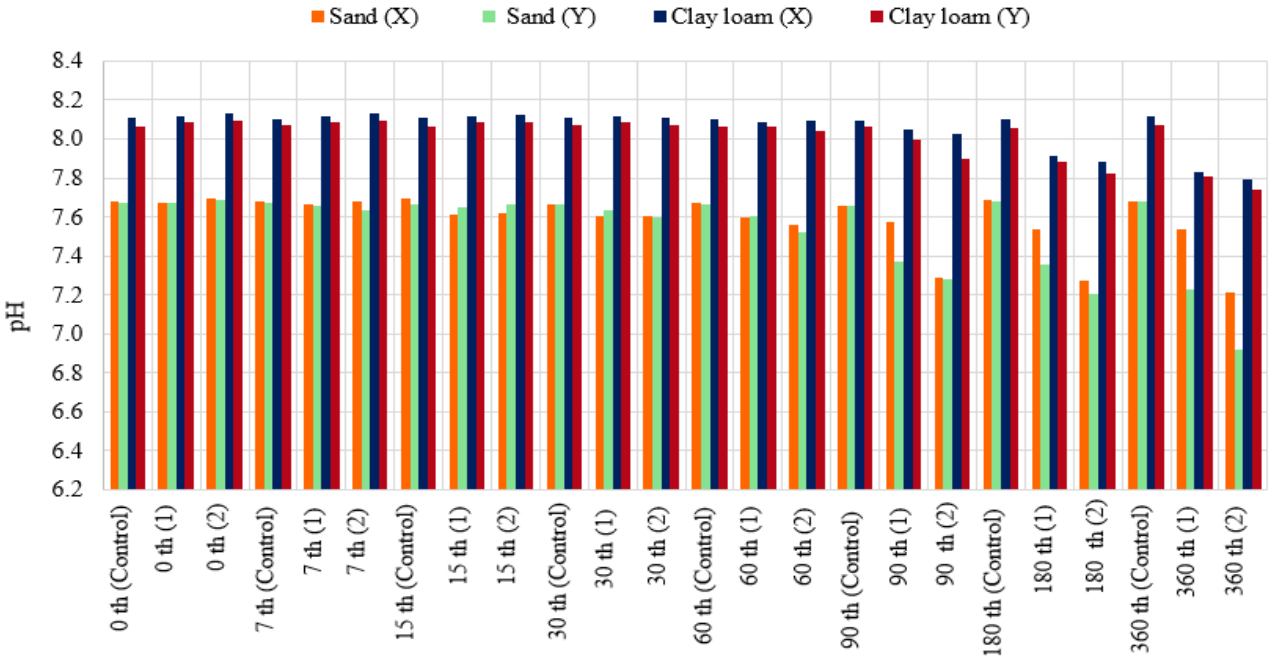

Figure 2. The effect of dose*application*time interaction on soil pH change

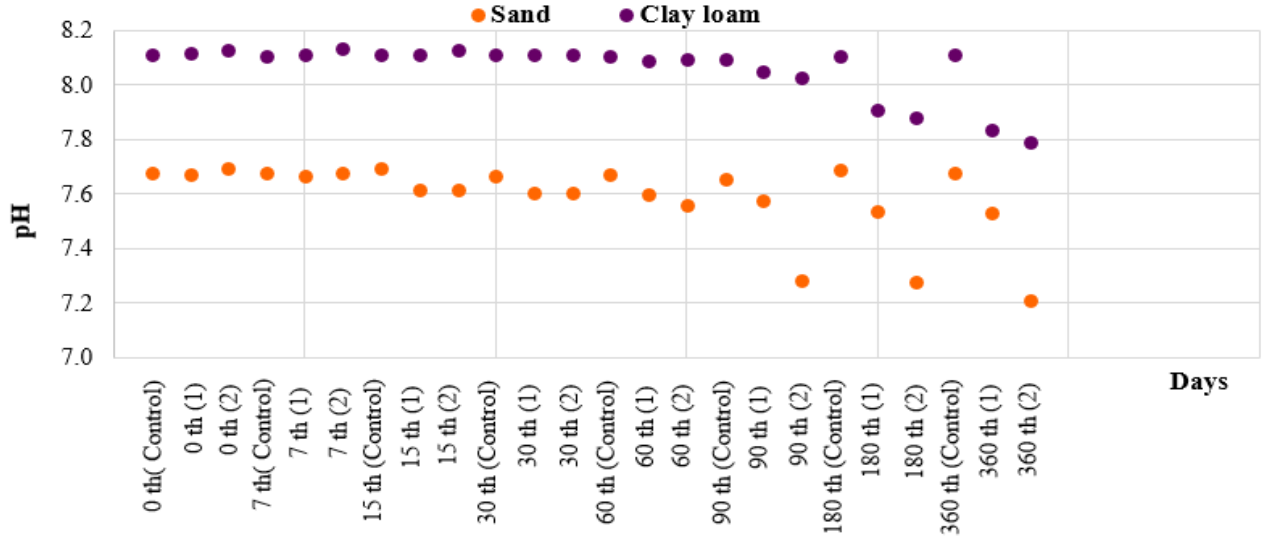

Figure 3. The impact of granular Sulphur applications on soil pH in sand and clay loam textures

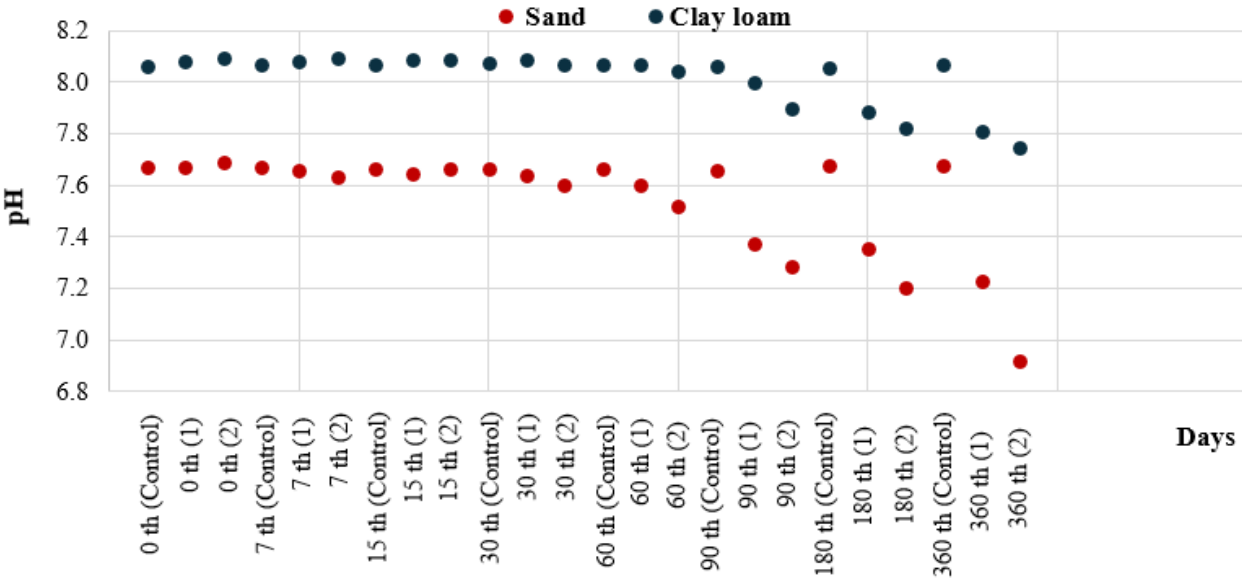

Figure 4. The influence of powdered Sulphur applications on soil pH in sandy and clay loam textures

This compound subsequently dissociates into calcium (Ca^{2+}) and sulfate ($SO_4{}^{2-}$) ions, effectuating a reduction in the soil pH from its initial state, an outcome that is significantly influenced by a multitude of factors including, but not limited to, the specific quantity of elemental S applied, the granular size distribution within the soil, and the intrinsic buffering capacity of the soil itself (Orman and Kaplan, 2000; Lisowska et al., 2022). Within the scope of the incubation experiments conducted, it was elucidated that alongside the establishment of optimal environmental conditions such as temperature and aeration, the dosage of S applied plays a pivotal role in expediting the oxidation process, thus leading to a discernible reduction in soil pH subsequent to the 60-day mark, albeit this reduction exhibits considerable variability when juxtaposed against the backdrop of differing soil textures. In their empirical investigation, Tabak et al., (2020) identified a relative reduction in soil pH after a period of 120 days in a soil possessing a loamy sandy texture, contingent upon the lime content, in comparison to a control group. Moreover, Zhao et al., (2015) delved into the intricate relationship between S oxidation and the physicochemical properties of soil, uncovering that in soils with a diverse composition of sand, silt, and clay, those samples exhibiting a lower buffering capacity witnessed a more accelerated reduction in soil pH, with the overarching effect on pH diminution being both temporally bound and dependent upon the structural composition of the soil. Similarly, Akay (2022) embarked on a study to ascertain the impact of biochar incorporation on the S uptake and growth of plants, with a specific focus on determining the optimal S fertilization dosage for the cultivation of turnips. This involved the integration of elemental S (0, 200, 400 mg kg^{-1}), S in sulfate form (0, 25, 50 mg kg^{-1}), and varying dosages of biochar (0, 1%, and 2%) into the growing medium. The findings from this study highlighted a statistically significant reduction in soil pH by 0.07 units within a clay-loamy textured soil when benchmarked against a control group ($p<0.01$), thus underlining the efficacy of S amendments in modulating soil pH.

Conclusion

The modulation of soil pH through the strategic application of S-based amendments emerges as a critical consideration in the realm of agronomic practices, particularly in contexts where soil pH levels are inherently elevated and pose a constraint to the bioavailability of essential nutrient elements for plants. The outcomes of this comprehensive study elucidate that S applications, emanating from a spectrum of sources, engender a pronounced reduction in soil pH across varied soil textural classes over the duration of the incubation period. This reduction, however, is subject to variation, predicated on the physicochemical attributes of the soil, including but not limited to, its particle size and buffering capacity. Furthermore, the investigation delineates that the application of 0.088 g of S culminates in the maximal reduction of soil pH across both soil textures by the 360th day, yet the practical feasibility and economic viability of this specific S dosage for field applications necessitates a reevaluation. Consequently, the exploration of alternative S sources or the adoption of lower S dosages (e.g., 0.044 g) is posited as a viable and economically judicious alternative for agronomic endeavors, with the overarching aim of optimizing S applications within soil management paradigms to foster the advancement of sustainable agricultural methodologies, thereby embracing an approach that harmoniously integrates environmental sustainability and cost-effectiveness.

Declarations

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Osman Sönmez; Design: Osman Sönmez.; Data Collection or Processing: Fatma Nur Kılıç.; Literature Search: Fatma Nur Kılıç.; Writing and Editing: Fatma Nur Kılıç, Osman Sönmez

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Evaluating the Nutritional and Safety Aspects of *Pyracantha coccinea*: Antioxidant Activity, Mineral, and Heavy Metal Content

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ABSTRACT

In this study, the fruits of *Pyracantha coccinea*, known for their ornamental and medicinal properties, were analysed to evaluate their antioxidant capacity, mineral content, and heavy metal concentrations. The antioxidant potential of *Pyracantha coccinea* was determined using DPPH, CUPRAC, and ABTS tests. Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES), Atomic Absorption Spectroscopy (AAS), and Gerthard Dumatherm techniques were used to determine the mineral and nutrient composition of the plant. As a result of the evaluation, calcium (0.25±0.02%), protein (4.29±0.47%), potassium (0.39±0.01%), magnesium (0.197±0.01%), sodium (0.08±0.01%), iron (0.012µg/g DW), aluminium (138±9.6 µg/g DW), cobalt (0.541±0.11 µg/g DW), chromium (0.422±0.05 µg/g DW), manganese (20±1.7 µg/g DW), zinc (43.9±4.6 µg/g DW), % DPPH (76.92±0.48) % ABTS value (77.52±0.39) and CUPRAC values (0.771±0.045 for 100ppm) were determined. In particular, the high levels of chromium (Cr) and zinc (Zn) in the fruits exceed the thresholds considered safe for medicinal applications and suggest that the heavy metal content in plants for medicinal use should be critically evaluated within acceptable limits. This study aims to explore the nutritional value and safety of *Pyracantha coccinea* by examining its antioxidant properties, mineral content, and potential heavy metal contamination. The findings will help shed light on its potential benefits and risks, offering valuable insight for its use in health, nutrition, and environmental applications.

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Introduction

Pyracantha coccinea, a perennial shrub belonging to the Rosaceae family, is characterized by its evergreen leaves and ability to grow up to three meters tall. This shrub, known as firethorn, thrives in many altitudes in regions including the Balkans, Europe, the Caucasus, and Turkey. The fruits of this plant are known for their bright red color, small size, and sweet taste. They are not only used to make jam. Still, they are also highly valued in traditional medicine for their beneficial effects on the body's overall health, heart function, and ability to increase urine production (Kambur & Tilki,2010; Keser, 2014). Furthermore, it has been determined that *Pyracantha coccinea* fruits have cytotoxic and antioxidant effects (Sharifi-Rad et al., 2020). The infiltration of ambient pollutants, such as toxic metals, into the world of plants poses a significant obstacle to the safe utilization of medicinal herbs. The buildup of metals such as chromium (Cr) and zinc (Zn) within cells can lead to many health issues, including the onset of cancer (Rodriguez-Fragosa et al., 2008). Therefore, medicinal plants must maintain heavy metal levels below predetermined safety thresholds. Heavy metal pollution is caused by industrial activities as well as the use of chemical pesticides and fertilizers in crops. These activities contribute to the movement of these metals into the surrounding ecosystem (Stanojkovic et al., 2015). In developing countries, medicinal plants have become an essential resource for over 80 percent of the population seeking relief from health complications concomitant with the rise in diseases that include cancer, diabetes, and cardiovascular disease (Seagel et al., 2019; Fridlender et al., 2015).

Macro and micronutrients are crucial for plant life as they are integral to the composition of enzymes that participate in different metabolic processes. Plants exhibit numerous morphological and physiological alterations in their deficits, particularly chlorosis, color changes, leaf curving, leaf spotting, and leaf abscission. The concentrations of major and trace elements in plants are determined by the geochemical characteristics of the soil and the plant's capacity for selective element

accumulation. Furthermore, contaminating plants with environmental constituents from air or water enables certain plants to be bioindicators of environmental pollution (Queralt et al., 2005). The permissible concentrations of elements in plants are crucial for human consumption, as these elements can be transferred to people via the food chain (Peralta-Videa et al., 2009). Examining medicinal plants has revealed that several sources can lead to their pollution with heavy metals. Consequently, it is imperative to recognize these plants' mineral and heavy metal composition to effectively utilize their healing properties while avoiding the dangers of toxicity. The antioxidant capacity of plants can be accurately measured using CUPRAC, ABTS, and DPPH methods, which are well-established methods known for their reliability and cost-effectiveness (Sharifi-Rad et al., 2020)

This research evaluates the elemental and heavy metal composition and investigates the antioxidant activity of Pyracantha coccinea fruits obtained from Van, Turkey. It aims to explore the nutritional value and safety of *Pyracantha coccinea* by examining its antioxidant properties, mineral content, and potential heavy metal contamination. The findings will help shed light on its potential benefits and risks, offering valuable insight for its use in health, nutrition, and environmental applications.

Materials and Method

Firethorn fruits were collected in July 2023 from the garden of a site 20km from the motorway at an altitude of 1720 m (latitude: 38°34'47.65 'N and longitude: 43°16'18.24 'E) in Van, Turkey. The plant was identified by specialist Dr. Murat Ünal and preserved at Van Yuzuncu Yil University Van F Herbarium with the code VANF 20555. For 25 days, the fruits of *Pyracantha coccinea* were dried at room temperature in a location shielded from direct sunlight. To inhibit moisture ingress into the fruits, a freeze-drying procedure was employed using a lyophilization device, operating at a pressure setting of 50 millitorr and a temperature of -80°C, extended over 72 hours.

Treatments Applied to the Plant Material

Two hundred milligrams of dried plant material were dissolved in Teflon tubes at a temperature of 180°C and a pressure of 32 bar for 40 minutes using the Milestone Ethos Microwave digestion system. Following microwave treatment, the samples were placed into 50 ml tubes and adjusted with Ultrapure Milli-Q water until they reached a final volume of 50 ml. The plant samples were evaluated using atomic absorption spectrometry (ICP-OES icap 6000 series, Thermo Scientific).

Procedure for ICP-OES and AAS Analyses

Concentrations of Al, Ag, Cd, As, Cr, Co, Cu, Mo, Pb, Ni, Zn, Fe, Mn, and Se were determined by using ICP-OES. Na, Mg, Ca, and K levels were measured using the AAS instrument. Analyses were conducted in triplicate. All elemental concentrations are expressed in mg kg^{-1} dry weight.

Protein Analyses

The fruits were desiccated in darkness at ambient temperature (22±2°C) and ground using a grinding mill (IKA, A11 basic Analytical mill). Following the grinding of the desiccated plant materials, the quantities of nitrogen and protein were assessed using the Dumatherm Nitrogen-Protein apparatus (Gerhardt Analytical System, Germany). Approximately 50 mg of pulverized plant sample was weighed and composted in aluminum tin cups at 1000°C.

Extract Preparation

The fruits of *Pyracantha coccinea* were dried at room temperature and extracted using ethanol. The 1/10 w/v weighed lyophilized plant sample was kept in a magnetic stirrer in 80% acidified ethanol at 25°C for 24 hours. After centrifugation at 8000 rpm for 15 min at 20°C, the supernatant was evaporated at 110 rpm at 48°C to remove ethanol. The antioxidant capacity was determined by the CUPRAC, DPPH (2,2-diphenly-1-picrylhydrazyl), and ABTS (2,2'-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid)) methods. The extracts obtained were used in different volumes (25µg/ml, 50 µg/ml, 100 µg/ml, 125 µg/ml, 150 µg/ml) for DPPH, CUPRAC and ABTS assays. All extraction procedures were conducted three times. The standard antioxidant (BHT (butylated hydroxytoluene)) and extract were dissolved at a concentration of µg/mL.

Determination of antioxidant capacity by CUPRAC method

The antioxidant properties of the ready extracts were assessed at four distinct concentrations using the CUPRAC method. Cu (II), Neocuprin, and NH_4Ac (Ammonium acetate) buffer were added to the prepared samples and standards at final concentrations of 10, 25, 50, and 100 µg/mL, and absorbance was measured at 450 nm after one hour (Apak et al., 2008). The absorbance levels of the samples were assessed in comparison to the standards. BHT (Butylated Hydroxy Toluene) and α-tocopherol served as standards, with total antioxidant capacity and TEAC (Trolox equivalent antioxidant capacity) values measured in µg/ml for all extracts.

DPPH and ABTS analyses

The DPPH (2,2-diphenly-1-picrylhydrazyl) method was performed according to the procedures described by Brand-Williams et al. (1995). For the analysis, DPPH radical solution was produced in 0.1% (m/v) ethanol and stored in a light-free condition. The samples tested were produced at varying concentrations, and 2 mL of DPPH radical solution was combined with 2 mL of sample solution. These combinations were incubated at room temperature (24°C) in the dark for 30 min. The scavenging capability was evaluated in triplicate. The sample vials were kept in darkening and exposed to continuing rotation for thirty minutes. The absorption spectra of the mixtures at 517 nm were determined using a Multiskan SkyHigh microplate spectrophotometer (Thermo Fisher Scientific, USA). Ethanol was utilized for the blank. The DPPH capacity was measured according to the equivalent:

$$RSC = [(A0 - A1) \div A0] \times 100$$

RSC : DPPH Radical Scavenging Capacity (%)
A0 : Absorbance of DPPH solution
A1 : Absorbance of sample and DPPH mixture

The ABTS method described by Re et al. (1999) is used to evaluate a substance's antioxidant capacity. This method measures the capacity of $ABTS^{\bullet+}$ (2,2'-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid)) radical cation to be neutralized by an antioxidant. The $ABTS^{\bullet+}$ solution (2 mM) was mixed with potassium persulfate $K_2S_2O_8$ (2.5 mM) and incubated at room temperature in the dark for 4 hours. The prepared solution was diluted with ethanol before analysis; the absorbance was adjusted to 0.72± 0.02 at a wavelength of 734 nm. Pyracantha coccinea fruit extracts were prepared for analysis at 10, 25, 50, and 100 mg/mL concentrations. 20 µL of each solution was mixed with 200 µL of $ABTS^{\bullet+}$ solution, and the mixtures were incubated in the dark for 25 min. After infusion, the absorbance of the mixtures was measured using a Multiskan SkyHigh microplate spectrophotometer (Thermo Fisher Scientific, USA). The % ABTS capacity was measured in the same way as DPPH. The extracts' free radical scavenging capacity was expressed in both tests as percentage inhibition. BHT served as the reference antioxidant for antiradical properties.

Statistical Analysis

The statistical analyses were conducted using IBM SPSS 25 software. Data obtained from three independent replicates were summarized as mean ± standard deviation (SD). Differences among groups were evaluated using One-Way ANOVA. When significant differences were detected, Duncan's multiple range test was applied for pairwise comparisons at a significance level of $p < 0.001$. For comparisons between two groups, independent t-tests were applied following Levene's test for homogeneity of variances.

Results and Discussion

Mineral, Heavy Metal and Protein Amounts

The acceptable limits of plant elements are essential for plant growth and human health. Excessive or deficient concentrations of elements in plants can affect agricultural productivity and health risks in the food chain. Table 1 presents the acceptable concentration ranges for various essential elements and minerals in plants, as reported in the literature (Corlett et al., 2002; Kabata-Pendias, 2010; Taiz & Zeiger, 2010). These limits indicate the typical ranges found in healthy plants and are critical for evaluating nutrient status and potential toxicity. In this study, the amounts of Ca, K, Mg, and Na are within acceptable limits, as shown in Table 2. However, the amounts of Zn and Cr are above acceptable values (Table 3). This result was attributed to firethorns growing near motorways and being contaminated with vehicle exhaust gases. Likewise, it may be due to wastewater pollution and chemical fertilizers accumulated in the soil (Liu et al., 2023). Further studies are planned to clarify this result. Toxic levels of heavy metals in plants intended to be used as medicinal plants prevent the plant's therapeutic properties.

The elements identified in the medicinal plants examined in this study are essential and recognized for their significant physiological and biochemical functions in humans. Mn, Zn, and Cu are known for being very important for keeping the body's redox balance because they can eliminate harmful reactive oxygen species (Silva et al., 2019). Mn was detected below the values reported for realizing metabolic activities in plants. Iron is a crucial element of hemoglobin (Vogt et al., 2021). The low levels of Fe and Mn, which play an essential role in synthesizing primary and secondary metabolites in plants and participate in the structure of enzymes, may be associated with geographical, physiological, and genetic factors (Grace et al., 2003; Özay & Pehlivan, 2024). The lower than expected amount of Fe and Mn may also reduce the antioxidant capacity of the plant during its use as a medicinal plant. Cobalt is a component of vitamin B12 essential for red blood cell formation (Osman et al., 2021). Cadmium (Cd), copper (Cu), chromium (Cr), and zinc (Zn) can accumulate in the cells and cause health problems when they are at toxic levels (Rodrigez-Fragoso et al., 2008; Liu et al., 2023). Magnesium (Mg) and Calcium (Ca) are the predominant metallic constituents in numerous plants, as they are integral to chlorophylls, metalloenzymes, and secondary metabolites (Olukayode et al., 2003). Potassium (K) is crucial as a cofactor for various enzymes, particularly in maintaining cell turgor pressure and electroneutrality (Taiz & Zeiger, 2008).

The composition of the soils in which the plants are grown determines the heavy metal and mineral contents. Plants such as *Pyracantha coccinea* can accumulate heavy metals and minerals depending on environmental conditions and soil quality. The amount of accumulation may also differ based on the pollution level of the plant's growth location (Zhang et al., 2022). The protein amount (% 4.29) is determined with previous studies (Song et al., 2023).

Table1. The acceptable limits for some essential elements and minerals in plants

Elements in plants	Acceptable limits
Aluminum (Al)	1-200 (µg/g)
Zinc (Zn)	20-150 (µg/g)
Nickel (Ni)	0.1-5 (µg/g)
Chromium (Cr)	0.006-18 (µg/g)
Cadmium (Cd)	0.05-0.2 (µg/g)
Cobalt (Co)	0.02-0.5 (µg/g)
Copper (Cu)	5-30 (µg/g)
Iron (Fe)	50-250 (µg/g)
Manganese (Mn)	30-300 (µg/g)
Calcium (Ca)	0.2%-1.0%
Potassium (K)	1.0%-3.0 %
Sodium (Na)	0.01%-0.2%
Magnesium (Mg)	0.1%-0.5%

Table 2. Percentage (%) Values of Elements in *Pyracantha coccinea* Fruits

% Amounts of Elements and protein	Mean ±SD (%)
Protein	4.29±0.47
Ca	0.25±0.02
K	0.39±0.01
Mg	0.197±0.02
Na	0.08±0.04

The data were analyzed over three replicates. Values are presented as mean (Mean) ± standard deviation (SD), representing the percentage composition of elements and protein in *Pyrachantha coccineae* fruits. The values presented in this table are based on descriptive statistics."

Table 3. Mineral and Heavy Metal Concentrations in *Pyracantha coccinea* Fruits (µg/g)

Minerals and heavy metals	Mean ±SD (µg/g)
Fe	0.012±0.03
Al	138±9.6
Co	0.44±0.11
Cr	20±0.05
Cu	6.5±1.02
Mn	20±1.7
Zn	200±4.6

The data were analysed over three replicates. Values are presented as mean (Mean) ± standard deviation (SD), representing the percentage composition of elements and protein in *Pyrachantha coccineae* fruits. The values presented in this table are based on descriptive statistics."

Table 4. Percentage (%) antioxidant (DPPH and ABTS) values of *Pyracantha coccinea* Fruits

Method	*P.coccinea* (Mean ± SD)	BHT (Mean ± SD)
DPPH	76.92 ± 0.48^{b}	94.27 ± 0.21^{a}
ABTS	77.52 ± 0.39^{b}	93.36 ± 0.41^{a}

Values are represented as mean ± standard deviation (SD) for three replicates. Letters (a,b) denote significant differences between groups ($p < 0.001$) according to the independent t-test.

Table 5. Trolox Equivalent Antioxidant Capacity TEAC (µmol TE g−1 DW) of *P.coccinea*, BHT, and α-Toc determined by the CUPRAC method

Concentration (ppm)	*P.coccinea (Mean±SD)*	BHT (Mean±SD)	α-Toc
10 ppm	0.246 ± 0.005^{c}	0.95 ± 0.007^{a}	0.35 ± 0.005^{b}
25 ppm	0.495 ± 0.005^{c}	1.48 ± 0.003^{a}	0.69 ± 0.004^{b}
50 ppm	0.989 ± 0.03^{c}	$2.35 \pm 0{,}006^{a}$	1.17 ± 0.004^{b}
100 ppm	1.791 ± 0.04^{c}	$3.28 \pm 0{,}007^{a}$	2.18 ± 0.004^{b}

Values are represented as mean ± standard deviation (SD) for three replicates. Letters (a, b, c) denote significant differences among groups ($p<0.001$) according to One-way ANOVA and Duncan's multiple-range test.

Conducting is crucial for evaluating the capacity of plants to remediate polluted soil through bioremediation. Investigating plants' mineral and heavy metal composition is essential in environmental science, botany, and ecology. These studies help us better understand how plants react to environmental stress, how they play a part in the natural detoxification process of pollutants, and how they ultimately affect human health. The formulation of medicinal herbal concoctions necessitates employing botanicals harboring heavy metal concentrations below specified safety thresholds. Consequently, the surveillance and control of hazardous metal quantities in medicinal vegetation and their derivatives are imperative for preserving both the effectiveness and security of phytotherapeutic agents.

Antioxidant Capacity

A critical factor in assessing the health benefits attributed to dietary components is their ability to yield antioxidative agents. Multiple assays, such as CUPRAC, ABTS, and DPPH, are conducted to determine this potential. All three assays are recommended as uncomplicated, rapid, reliable, and affordable techniques for evaluating the antioxidant activity of plant-based herbal medicines. The capacity of antioxidants depends on numerous external elements, similar to the chemical profile of plants. These factors include inherited potential, preservation, soil composition, agronomic techniques, weather conditions, stressors during the growth season, and industrial procedures.

A common technique for evaluating the antioxidant capacity of natural extracts is the DPPH method, which is based on the reduction of DPPH by an antioxidant solution. According to the DPPH method obtained, the antioxidant activity value of *Pyracantha coccinea* in our study is 76.92 ± 0.48 % DPPH (100 µg/mL), the % ABTS (100 µg/mL) value is 77.52 ± 0.39 (Table 4), and CUPRAC is 0.77 TEAC (µmol TE g^{-1} DW) (for 100ppm) (Table 5). In acccordance with our study, the DPPH antioxidant activity of *Pyracantha coccinea* collected from different locations and extracted with different solvents was reported as 78.73 µg/mL (Keser, 2014), 500 µg/mL (Kerasioti et al., 2019) and 36.53 µg/mL (Semerci et al., 2020) in previous studies. In another study (Tüysüz et al., 2020), the CUPRAC value of *Pyracantha coccinea* was 2.871 µmol TE g^{-1} Dry Weight, DPPH antioxidant capacity as % 83.13 and ABTS as %79.34 TEAC (µmol TE g^{-1}DW) are reported. These differences in results could be explained by differences in

the geographical origin of plants, the time it takes to collect them, and the condition of extraction. Such factors, like temperature, time, and extraction methodology, are known to significantly affect the levels of antioxidant activity measured, which could explain discrepancies in these studies. The safe use of *Pyracantha coccinea* fruits depends on reducing heavy metal absorption. With proper precautions, they may serve as a significant resource for both dietary and medicinal purposes. Given the corroborative findings consistent with existing literature, our research recommends further research to thoroughly evaluate the medicinal effects of Pyracantha coccinea fruits for dietary applications.

Conclusion

Increased concentrations of certain heavy metals, especially chromium (Cr) and zinc (Zn) that are higher than recommended safety thresholds may make these plants less viable for use as medicinal plants. However, because of its high phenolic content, *Pyracantha coccinea* is well known for having vigorous antioxidant activity. This emphasizes its usefulness as a healthy dietary component. In conclusion, *Pyracantha coccinea* is promising in cytotoxic and antioxidant applications and has proven uses as a heavy metal biomonitor. However, there are still a lot of uncharted territories for future research. Notably, molecular identification and enhancement of bioactive compounds and broader pharmacological assessments are warranted.

Declarations

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Detection of Prunus Necrotic Ringspot Virus (PNRSV) and Apple Mosaic Virus (ApMV) in Rose (*Rosa* spp.) Plants in Konya Province

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ABSTRACT

This research was conducted to determine the presence of *Prunus necrotic ringspot virus* (PNRSV) and *Apple mosaic virus* (ApMV) that can cause infection in rose (*Rosa* spp.) plants grown in Konya province. For this purpose, field and laboratory studies were carried out in areas where roses are mostly grown for landscaping purposes, and infection rates were calculated with the data obtained. The hypothesis of the study is that roses in Konya province may be infected with PNRSV and ApMV and the presence of these viruses can be determined. In line with this hypothesis, various rose growing areas in Konya province were selected as the research area. During the field studies in 2023, guided sampling was carried out and 94 leaf, branch and flower samples were collected from different rose varieties. The collected samples were tested for determining of PNRSV and ApMV infections by Double Antibody Sandwich (DAS) ELISA method, which is one of the serological testing methods in the laboratory. As a result of the tests, it was revealed that the single infections of PNRSV and ApMV were present in 12 and 11 samples of rose plants in Konya province. The total infection rate of both viruses in the province was calculated as 24.47%. Also, PNRSV+ApMV mixed infections were detected in 2 samples. In this study, the infections of PNRSV and ApMV on roses in Konya province were determined for the first time by serological methods. These results will serve as an important source of information for rose producers and agricultural engineers in the region and will allow the development of strategies to control the spread of viruses and minimize infections.

Türk Tarım – Gıda Bilim ve Teknoloji Dergisi, ?(?): ???-???, ????

Konya İlinde Gül (*Rosa* spp.) Bitkisinde Enfeksiyon Oluşturan Erik Nekrotik Halkalı Leke Virüsü (PNRSV) ve Elma Mozaik Virüsü (ApMV)'nün Varlıklarının Belirlenmesi

MAKALE BİLGİSİ

Araştırma Makalesi

Geliş : 15.11.2024
Kabul : 23.12.2024

Anahtar Kelimeler:
ApMV
DAS-ELISA
Gül
Konya
Mozaik

ÖZ

Bu araştırma, Konya ilinde yetiştirilen gül (*Rosa* spp.) bitkisinde enfeksiyon oluşturabilen Erik Nekrotik Halkalı Leke Virüsü (PNRSV) ve Elma Mozaik Virüsü (ApMV)'nün varlıklarının belirlenmesi amacıyla yürütülmüştür. Bunun için, daha çok peyzaj amaçlı gül yetiştiriciliği yapılan alanlarda arazi ve laboratuvar çalışmaları gerçekleştirilmiş, elde edilen veriler ile hastalık oranları hesaplanmıştır. Çalışmanın hipotezi, Konya ilindeki güllerin PNRSV ve ApMV ile enfekte olabileceği ve bu virüslerin varlıklarının tespit edilebileceğidir. Bu hipotez doğrultusunda, araştırma sahası olarak Konya ilindeki çeşitli gül yetiştirme alanları seçilmiştir. 2023 yılında gerçekleştirilen arazi çalışmalarında, güdümlü örnekleme yapılmış ve farklı gül çeşitlerinden 94 adet yaprak, dal ve çiçek örnekleri toplanmıştır. Toplanan örnekler, laboratuvar ortamında serolojik testleme yöntemlerinden bir tanesi olan Double Antibody Sandwich (DAS) ELISA yöntemi ile PNRSV ve ApMV'nin enfeksiyonları için testlenmişlerdir. Testlemelerin sonucunda, Konya ilindeki gül bitkilerinde PNRSV'nin 12, ApMV'nin ise 11 örnekte tespit edildiği ortaya konulmuştur. Her iki virüsün ildeki toplam enfeksiyon oranları ise %24,47 olarak hesaplanmıştır. Ayrıca, 2 örnekte ise PNRSV+ApMV karışık enfeksiyonları saptanmıştır. Gerçekleştirilen bu çalışma ile PNRSV ve ApMV'nin Konya ilindeki güller üzerindeki enfeksiyonları serolojik yöntemlerle ilk kez tespit edilmiştir. Bu sonuçların, bölgedeki gül üreticileri ve bitki sağlığı uzmanları için önemli bir bilgi kaynağı görevi göreceği, virüslerin yayılımını kontrol altına almak ve enfeksiyonları minimize etmek için stratejilerin geliştirilmesine olanak sağlayacağı düşünülmektedir.

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Giriş

Gül (*Rosa* spp.) bitkisi, estetik değeri ve ekonomik getirisi yüksek olan süs bitkileri arasında önemli bir yer tutmaktadır. Bu süs bitkisi Türkiye'de hem kesme çiçek amaçlı, hem de kozmetik sektöründe kullanılmak üzere gül yağı üretmek amacıyla yetiştirilmektedir. Dünya genelinde yıllık yaklaşık 15.000 ton gül üretilmekte olup, Türkiye ve Bulgaristan gibi ülkeler bu üretimde öncü konumdadır (Torusdağ ve Bakkalbaşı, 2019). Türkiye, özellikle yağlık gül üretiminde dünya lideridir ve dünya gülyağı talebinin % 50'sini karşılamaktadır. 2020 yılında yaklaşık 41.320 da alanda yağlık amaçlı gül yetiştiriciliği gerçekleştirilmişken kesme çiçek amaçlı 2.844 da alanda ise yaklaşık 94 milyon adet gül çiçeği elde edilmiştir. Gül, Türkiye'nin çeşitli illerinde önemli bir tarımsal ürün olarak yetiştirilmektedir. Özellikle Isparta, Antalya ve Konya gibi iller, ülkemizde gülcülüğün merkezi konumundadır. Bu iller hem güllerin geniş alanlarda yetiştirildiği hem de gülyağı üretiminin yoğun olarak yapıldığı bölgelerdir (Anonim, 2022; 2024). TÜİK verilerine göre, yaklaşık 20 milyon dekar tarım alanına sahip olan Konya ili, Türkiye'nin önemli tarım bölgelerinden biri olup, gül yetiştiriciliği açısından da potansiyel barındırmaktadır (Anonim, 2024).

Dünyada, gül yetiştiriciliğinde verim ve kaliteyi olumsuz yönde etkileyen 11 farklı virüs türünün enfeksiyonları tespit edilmiştir (Kısa ve Korkmaz, 2021). Dünyanın çeşitli gül üretim alanlarında; *Arabis mosaic virus* (ArMV), *Apple mosaic virus* (ApMV), *Prunus necrotic ringspot virus* (PNRSV), *Strawberry latent ringspot virus* (SLRSV), *Tobacco ringspot virus* (TRSV), *Tobacco streak virus* (TSV) ve *Tomato ringspot virus* (ToRSV) enfeksiyonları saptanmıştır. İlgili literatüre bakıldığında, global düzeyde güllerde en yaygın şekilde görülenleri ve en önemli olanları Erik nekrotik halkalı leke virüsü (PNRSV) ve Elma mozaik virüsü (ApMV) olduğu görülmektedir (Erdiller ve ark., 1995; Fulton, 1970; Manners, 1997; Sipahioğlu ve ark., 2001; Yardımcı ve Çulal, 2009).

Gül bitkilerinde, PNRSV ve ArMV enfeksiyonları, Türkiye'de ilk kez Erdiller ve ark. (1995) tarafından tespit edilmişlerdir. Yardımcı ve Kılıç (2009) ise Isparta ilindeki yağlık gül bahçelerinden topladıkları simptomatik bitki örneklerinde gerçekleştirdikleri serolojik testler sonucunda, PNRSV, ApMV ve ArMV virüslerini tespit etmişlerdir.

Erik Nekrotik Halkalı Leke Virüsü (PNRSV), *Ilarvirus* genusunda yer alır ve zarflı olmayan, isometrik ve basiliform virionlardan oluşur. *Rosa* türleri başta olmak üzere *Prunus* türleri (kiraz, vişne, erik, badem, şeftali) ve *Humulus lupulus* (şerbetçi otu) gibi bitkilerde doğal konukçuluk yapar (Nemeth, 1986). Ekonomik açıdan büyük önem taşıyan bu bitkilerde PNRSV, çeşitli ırklarıyla ciddi zararlar verebilir (Nyland ve ark., 1976; Fulton, 1981). PNRSV'nin yayılması genellikle aşı, çelik veya fidanlar aracılığıyla gerçekleşir. Enfekte fideler veya aşılarla sağlıklı ağaçlara virüs bulaşabilir ve bu da hastalığın yayılmasına yol açabilir. Virüs ayrıca aşılı tomurcuklar veya meyve ağaçlarında da enfeksiyon oluşturabilir (Güran, 2007).

Güllerde görülen "gül mozaik" hastalığı, özellikle *Prunus necrotic ringspot virus* (PNRSV) tarafından oluşturulan enfeksiyonlar çiçek üretiminde önemli kayıplara neden olabilir. Çalışmalar, PNRSV'nin güllerde çiçek üretiminde %40'a varan azalmalara yol açabildiğini göstermektedir (Thomas, 1980). Bu virüs ayrıca çiçeklerde deformasyonlara, renk kırılmalarına, çiçeklerin yaş ve kuru ağırlıklarında azalmalara ve geç çiçeklenmelere neden olabilir.

Özellikle kesme gül yetiştiriciliğinde, PNRSV enfeksiyonları goncaların küçülmesine, bitkinin zayıflamasına ve çiçeklerde renk kırılmalarına yol açarak pazar değerini düşürebilir (Thomas, 1980). Bu durum ekonomik kayıplara sebep olabilir ve güllerin ticari değerini azaltabilir.

Elma Mozaik Virüsü partikülleri, 25 ve 29 nm çapında izometrik şekilli, ssRNA genomuna sahiptir. Bu virüsün genomu; RNA 1, RNA 2 ve RNA 3 olmak üzere 3 parçalı ve bunlara ilaveten subgenomik RNA (RNA 4)' dan ibarettir (Shiel ve Berger, 2000).

Virüs, ülkemizde elma, fındık, erik ve böğürtlen gibi ekonomik öneme sahip meyve ağaçlarında ve birçok bölgemizdeki güllerde tespit edilmiş olmasının yanında armut ve ayvada da enfeksiyon yaptığına dair kayıtlar mevcuttur (Akbaş ve Ilhan, 2005; Arlı Sökmen ve ark., 2005; Çağlayan ve ark., 2006; Korkmaz ve ark., 2013; Uzunoğulları ve İlbağı, 2009; Yardımcı ve Çulal Kılıç, 2009).

Gül mozaik hastalığı hem PNRSV hem de ApMV tarafından oluşturulabilir. Hastalığın karakteristik belirtileri arasında yapraklarda klorotik halkalar ve çizgiler, genel büyümede gerileme bulunur. PNRSV, ApMV'ye göre daha yaygın olarak güllerde görülür ve çiçeklenmeyi geciktirebilir. Ayrıca PNRSV enfeksiyonları çiçeklerin büyüklüğünün ve sayısının azalmasına, deforme olmuş çiçeklerin sayısının artmasına neden olabilir (Bjarnason ve ark., 1985).

Prunus necrotic ringspot virus ve *Apple mosaic virus*, çeşitli bitki türlerinde de enfeksiyona neden olan önemli bitki virüsleri arasındadır ve gül bitkilerinde çeşitli zarara neden olabilirler. Konya ilinde daha önce bu konuyla ilgili bir çalışma yapılmamıştır. Çeşitli virüslerin varlığını ve yaygınlığını araştırmak, bu virüslerle mücadele edebilmek için etkili yöntem stratejileri geliştirmek için önemlidir.

Materyal ve Yöntem

Örneklerin Toplanması

Araştırma materyalini oluşturan hastalıklı bitki örnekleri Konya ilinin Meram, Selçuklu ve Karatay merkez ilçelerinde 2023 yılının sonbahar ((Eylül-Kasım) aylarında gül bitkilerinin bulunduğu park ve bahçelerden belirti gösteren bitkilerden toplanan 94 adet yaprak, dal ve çiçek örneği bu çalışmanın ana materyalini oluşturmuştur.

Materyali oluşturan örnekler, Meram Gödene Mahallesi, Kozağaç Parkı, Hobi Bahçesi ve Karaaslan Hadimi Parkı; Selçuklu Alaaddin Tepesi, Japon Parkı ve Kültürpark Gül Bahçesi; Karatay Şehir Parkı ve Olimpiyat Parkı gibi merkez ilçelerde bulunan çeşitli park bahçe ve hobi amaçlı yetiştiriciliği yapılan yerlerden güdümlü örnekleme yapılarak toplanmıştır.

Yapraklarında; mozaik, klorotik desenler, klorotik benek veya lekeler, klorotik halkalı lekeler, solgunluk ve şekil bozuklukları, çiçeklerde; renk kırılmaları, şekil bozuklukları bitkinin genelinde ise gelişme gerilikleri ve cücelik gibi belirtiler gösteren gül bitkilerinden örneklemeler gerçekleştirilmiştir. Örnekler Meram İlçesi 4 farklı yer 46 örnek; Selçuklu İlçesi 3 farklı yer 30 örnek; Karatay İlçesi 2 farklı yer 18 örnek olmak üzere toplamda 9 farklı yerden 94 örnek toplanmıştır. Toplanan örnekler isimlendirilerek ve numaralandırılarak polietilen torbalara

konulmuştur. Etiketlenen örnekler, toplanma anından itibaren -20°C sabit sıcaklıkta derin dondurucuda saklanmak üzere polietilen torbalara konulmuş ve laboratuvara buz kutuları içinde taşınmıştır.

DAS-ELISA Testi

Park ve bahçelerden PNRSV ve ApMV ile bulaşık olduğu düşünülen gül bitki örnekleri toplanmış ve Double Antibody Sandwich (DAS) ELISA yöntemi kullanılarak testlenmiştir. Bunun için PNRSV ve ApMV virüslerine spesifik antiserumlar, ticari olarak temin edilmiştir. Örneklerin hazırlanması ve test işlemlerinin gerçekleştirilmesi için ELISA plakaları, mikro pipetler, plastik kaplar, cam malzemeler, pastör fırını, inkübatör, buzdolabı, ekstraksiyon, kaplama, conjugate, substrat ve yıkama tampon çözeltileri ve ELISA plaka okuyucusu gibi laboratuvar ekipmanları kullanılmıştır.

Konya ili merkez ilçelerinden 9 farklı yerden toplanan materyaller serolojik test çalışmaları yapılıncaya kadar -20°C sabit sıcaklıkta bulunan derin dondurucuda muhafaza edilmiştir.

Hastalık simptomları gösteren bitkilerden alınan 94 örnek, PNRSV ve ApMV virüslerinin olası enfeksiyonlarının tespit edilmesi amacıyla Double Antibody Sandwich Enzyme Linked Immuno Sorbent Assay (DAS-ELISA) yöntemi ile teste tabi tutulmuşlardır. 9 farklı yerden toplanan 94 farklı bitki örneği tek tek hassas terazide 1 g tartıldıktan sonra içlerinde 1:10 oranında PBS-TP (pH:7,4) bulunan plastik ezme poşetlerinin içine koyulmuştur. Daha sonra poşetler içindeki gül örnekleri homojen olacak şekilde manuel homojenizatör kullanılarak iyice ezilmiştir. Elde edilen bitki ekstraktları mikropipet yardımıyla falkon tüplerine aktarılmıştır. Tüplerin üzerine gerekli olan bilgiler yazıldıktan sonra bunlar testleme çalışmaları için +4 °C buzdolabında muhafaza edilmiştir. ELISA testi Clark ve Adams (1977)'a göre ELISA kitinin alındığı firma (Bioreba)'nın önerdiği şekilde uygulanmış ve her örnek için 2 tekerrürlü olacak şekilde yapılmıştır. ELISA testi sonuçları, öncelikle kuyucukların görsel olarak kontrol edilmesiyle ve ardından ELISA okuyucusunda OD405 değerinin alınmasıyla elde edilmiştir. Negatif kontrol kuyucuğuna ait OD405 değerinin en az iki katı ve üzerinde değer veren kuyucuklardaki örnekler virüsle enfekteli (pozitif) olarak kabul edilmiştir. ELISA testlerinde her bir örnek için ikişer adet kuyucuk kullanılmış ve her bir ELISA pleytinde ikişer adet pozitif (infekteli), negatif (sağlıklı) ve buffer kontrol bulunmasına dikkat edilmiştir.

Bulgular ve Tartışma

Sürvey Çalışmaları

Konya ilinde gül yetiştiriciliği yapılan park ve bahçelerde yapılan sürveylerde bazı gül bitkilerinin yapraklarında klorotik lekeler, çizgili leke, halkalı leke, kıvırcıklık, rozetleşme, çiçeklerde renk açılması ve bitki genelinde solgunluk, şekil bozuklukları gibi virüs hastalıkları belirtilerine sahip gül bitkileri gözlenmiş ve bu bitkilerden örneklemeler gerçekleştirilmiştir (Şekil 2,3,4).

DAS-ELISA Testinden Alınan Sonuçlar

Arazi çalışmaları sırasında, virüs enfeksiyonu belirtileri gösteren gül bitkilerinden 94 yaprak örneği toplanmış ve bu örneklere PNRSV ve ApMV virüslerinin varlığını tespit etmek amacıyla DAS-ELISA testi uygulanmıştır. Test sonuçları, sağlıklı bitki örneklerinden elde edilen ve negatif kontrol olarak kullanılan bitki ekstraktlarının absorbans değerinin iki katı veya daha yüksek değerler gösteren örneklerin virüs enfeksiyonu açısından pozitif kabul edilmesi şeklinde değerlendirilmiştir. Ayrıca, virüse pozitif reaksiyon veren örneklerin bulunduğu kuyucuklarda sarı renk oluştuğu gözlemlenmiştir. DAS-ELISA test sonuçlarına göre, test edilen örneklerden 23 tanesinin virüslerle enfekte olduğu belirlenmiştir (Çizelge 2, 3).

Çizelge 1. İlçelere göre örnek toplanan park- bahçe ve toplanan örnek sayısı
Table 1. Number of parks and gardens and number of samples collected by districts

Örnek toplanan ilçeler	Örnek toplanan park-bahçe sayısı	Toplanan örnek sayısı
Meram	4	46
Selçuklu	3	30
Karatay	2	18
Toplam	9	94

Şekil 1. Survey çalışmaları sırasında gül bitkilerinde gözlenen belirtiler (a,c: yapraklarda kloroz ve çiçeklerde renk açılmaları; b,d: yapraklarda lekelenmeler ve şekil bozuklukları)
Figure 1. Symptoms of virus diseases on rose which were observed during survey studies. (a,c: chlorosis on leaves and colour breakings on flowers; b,d: deformations and flecks on leaves)

Çizelge 2. Konya ili park ve bahçelerinden toplanan gül örneklerindeki PNRSV ve ApMV enfeksiyonları
Table 2. PNRSV and ApMV infections in rose samples collected from Konya province parks and gardens

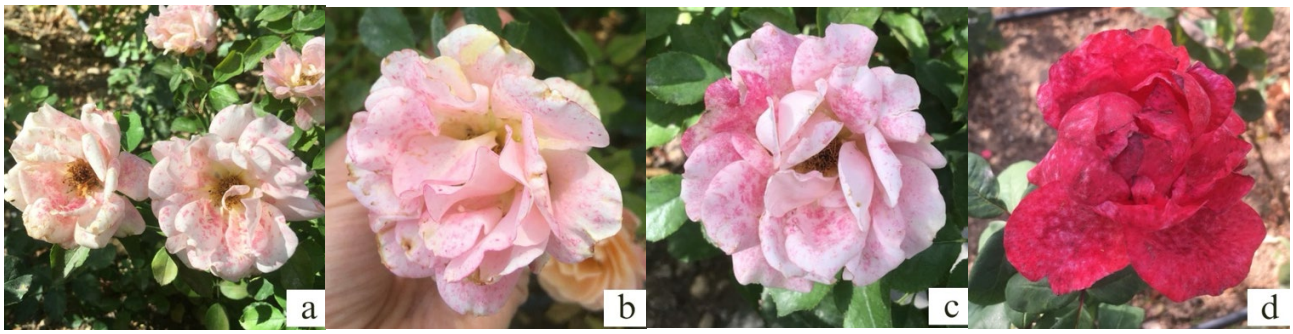
Örnek Toplanan Yerler	Örnek Sayısı	PNRSV	ApMV
Gödene Mahallesi	4	1	–
Kozağaç Parkı	18	2	1
Meram Hobi Bahçesi	14	1	1
Karaaslan Hadimi Parkı	10	1	–
Selçuklu Alaaddin Tepesi	12	3	6
Japon Parkı	4	2	–
Kültürpark Gül Bahçesi	14	–	1
Karatay Şehir Parkı	3	–	–
Olimpiyat Parkı	15	2	2
Toplam	94	12	11

Çizelge 3. Konya merkez ilçelerinden toplanan gül örneklerindeki PNRSV ve ApMV enfeksiyonları oranları
Table 3. Rates of PNRSV and ApMV infections in rose samples collected from Konya central districts

Örnek toplanan ilçeler	Testlenen örnek sayısı	Pozitif örnek sayısı	PNRSV	ApMV	PNRSV + ApMV	Enfeksiyon oranı (%)
Meram	46	7	5 (%10,87)	2 (%4,35)	–	15,22
Selçuklu	30	12	4 (%13,33)	6 (%20)	2 (%6,66)	40
Karatay	18	4	2 (%11,11)	2 (%11,11)	–	22,22
Toplam	94	23	11(%11,7)	10(%10,64)	2 (%2,13)	24,47

Şekil 2. Gül yapraklarında virüs hastalıkları sebebiyle görülen klorotik desenler
Figure 2. Chlorotic patterns on rose leaves due to virus diseases

Şekil 3. Gül yapraklarında mozaik, kloroz ve şekil bozuklukları
Figure 3. Mosaic, chlorosis and deformations on rose leaves



Şekil 4. Çiçekte renk kırılması belirtisi (a, b, c, d)
Figure 4. Colour breaking symptoms on flower (a, b, c, d)

Meram ilçesinde bulunan park ve bahçelerden (Gödene Mahallesi, Kozağaç Parkı, Meram Hobi Bahçesi, Karaaslan Hadimi Parkı) toplanan 46 gül bitkisi örneğinin 5'inin PNRSV ile; 2'sinin ApMV ile bulaşık olduğu tespit edilmiştir.

Selçuklu ilçesinde bulunan park ve bahçelerden (Selçuklu Alaaddin Tepesi, Japon Parkı, Kültürpark Gül Bahçesi) toplanan 30 örnekten 5'inin PNRSV ile; 7'sinin ApMV ile bulaşık olduğu tespit edilmiştir.

Karatay ilçesinde bulunan park ve bahçelerden (Karatay Şehir Parkı ve Olimpiyat Parkı) toplanan 18 örneğin 2'sinin PNRSV ile; 2'sinin ApMV ile bulaşık olduğu tespit edilmiştir.

Çizelge 2.'de de görüldüğü üzere sadece Karatay Şehir Parkı'ndan toplanan örneklerde her iki virüse de rastlanmamıştır.

Yapılan araştırma sonucunda virüs ile enfekteli olduğu belirtisi gösteren 94 örneğin 11 tanesinin PNRSV ile 10 tanesinin ApMV ile ve 2 tanesinin PNRSV + ApMV ile bulaşık olduğunun tespit edilmesi, toplanan örneklerde farklı virüslerin de bulunabileceğini göstermektedir (Çizelge 2, 3).

Bu araştırma sonucunda, Konya ilinde yetiştirilen gül bitkilerinde tespit edilen ApMV ve PNRSV, yine DAS-ELISA testlemeleri ile ülkemiz ve dünyanın farklı bölgelerinde yetiştirilen farklı konukçu bitkilerinde teşhis edilmişlerdir. Türkiye'de gül bitkilerinde söz konusu virüslerin tespiti yönünde az sayıda çalışma (Akpınar, 2009; Erdiller ve ark., 1995, Güran, 2007; Yardımcı ve Çulal, 2009) olmasına karşılık özellikle sert ve yumuşak çekirdekli meyve ağaçlarında birçok çalışmaya rastlanılmaktadır (Akgül ve ark., 2021; Amet, 2021; Canik ve ark., 2011; Çelik ve Ertunç, 2019; Öztekin ve Buzkan, 2012; Yardımcı ve Eryiğit, 2006).

Sunulan bu araştırma sonuçlarına paralel olarak; Erdiller ve ark. (1995) tarafından Samsun gül yetiştirme alanlarından toplanan simptomatik gül bitki kısımlarında PNRSV enfeksiyonları serolojik olarak ortaya konulmuştur. Benzer olarak, Şanlıurfa ilinde güllerde yapılan bir çalışmada ELISA ve RT-PCR teknikleriyle PNRSV tespit edilmiştir. Belirti gösteren 19 bitki örneği toplanmıştır. ELISA testi sonuçlarında toplanan 19 örneğin 4'ü; RT-PCR yöntemi sonucunda toplanan 19 örneğin 6'sı pozitif olarak saptanmıştır (Güran, 2007). Akpınar (2009) tarafından yapılan çalışmada Edirne, İstanbul, Kırklareli ve Tekirdağ illerinden hastalık belirtileri sergileyen gül bitkilerinden 287 yaprak örneği toplanmıştır. Toplanan örneklerde DAS-ELISA test yöntemiyle *Prunus necrotic ringspot virus* (PNRSV), *Apple mosaic virus* (ApMV) ve *Strawberry latent ringspot virus* (SLRSV) virüslerinin varlığı saptanmaya çalışılmıştır. Sonuç olarak örneklerin 18'inde (%6,27 enfeksiyon oranı) ApMV'nin, 17'sinde (%5,92 enfeksiyon oranı) PNRSV'nin ve 7'sinde (%2.43 enfeksiyon oranı) de her iki virüsün bulunduğu saptanmıştır. Yine, yapılan diğer bir çalışma ise, ApMV'nin ülkemizde elma, fındık ve yağ gülünde yaygın olarak görüldüğünü göstermiştir (Canik ve ark., 2011).

Söz konusu iki virüs hastalığının özelilkle konukçuları olan meyve ağaçlarında tespit edilmesine yönelik bir çok araştırma gerçekleştirilmiştir. Örneğin, Isparta ili elma bahçelerinden toplanan simptomatik elma yapraklarında serolojik olarak Elma mozaik virüsü (ApMV), 274 örneğin 82'sinde belirlenmiştir (Yardımcı ve Eryiğit, 2006). Bursa ilinde şeftalide PNRSV için bir araştırma yapılmıştır. Şeftali yetiştirme alanlarından ve yakınındaki bir elma bahçesinden simptomlar gösteren yapraklar toplanmıştır. Alınan yaprak örnekleri ELISA ve RT-PCR ile PNRSV için test edilmiştir. Bu çalışmada bitkilerin hem RT-PCR hem de ELISA ile PNRSV ile enfekteli olduğu bulunmuştur (Çelik ve Ertunç, 2019). Amet (2021) tarafından yapılan çalışmada ise, *Plum pox virus* (PPV) ve *Prunus necrotic ringspot virus* (PNRSV) hastalıklarını saptamak amacıyla Tekirdağ ili sert çekirdekli meyve ağaçlarından 158 adet yaprak örneği toplanmıştır. Toplanan yaprak örnekleri DAS-ELISA testi ile araştırılarak 16 adet örneğin (%10,13) PPV ile 4 adet örneğin ise (%2,53) PNRSV ile enfekteli olduğu saptanmıştır. Her iki virüsün neden olduğu ildeki toplam enfeksiyon oranı ise %12,66 olarak bulunmuştur. Milleza ve ark., (2013) tarafından Yeni Zelanda da yapılan bir çalışmada, özel ve halka açık bahçeler, ticari seralar ve farklı bölgelerden 89 gül örneği toplanmıştır. Bu örnekler, gülleri enfekte ettiği bilinen virüsler için RT-PCR ile test edilmiştir. Test edilen 89 bitki örneğinin %22'sinin PNRSV ile enfekteli olduğu ortaya konmuştur. Ekvador'un Pichincha eyaletindeki virüs belirtileri gösteren güllerde ApMV varlığından şüphelenilmiştir. Paz ve ark., (2020) tarafından şüphelenilen bitkilerden 15 yaprak örneği alınarak DAS-ELISA ile test edilmiş ve bunlardan dördünün ApMV ile enfekteli olduğu tespit edilmiştir. Yine, Hindistan'da yürütülen bir araştırma kapsamında, Wani ve ark., (2022) virüs enfeksiyonu belirtileri gösteren toplam 236 gül örneği toplanmıştır. Toplanan bitki örnekleri RT-PCR ile test edilmiş ve ApMV ve PNRSV etmenlerinin varlığı tespit edilmiştir.

Ülkemizde, gül yetiştirme alanlarındaki viral hastalıkları tespit etmek amaçlı gerçekleştirilen çalışmalarda, sunulan bu çalışmada bakılmayan farklı virüs hastalıkları da ortaya konulmuştur. Yardımcı ve Kılıç (2010) tarafından yapılan bir çalışmada Isparta ilinde yağlık güllerde DAS-ELISA yöntemi ile virüs şüpheli 142 yaprak örneği test edilmiş ve 36 örnekte SLRSV enfeksiyonu saptanmıştır. Yapılan bu çalışmada örneklerin %25,4 oranında SLRSV ile enfekteli olduğu belirlenmiştir. Başka bir araştırmada ise Çanakkale ilinde virüs benzeri simptom gösteren 71 gül örneği toplanmış ve toplanan örnekler PCR ile test edilmiştir. Testlemeler sonucunda 71 örneğin 19'u *Rose yellow vein virus* (RYVV) ile enfekteli olarak bulunmuştur (Kısa ve Korkmaz, 2021).

Yapılan çalışmalar göstermektedir ki, güllerde PNRSV ve ApMV'nin yanında *Tobacco streak virus* (TSV), *Arabis mosaic virus* (ArMV), *Strawberry latent ringspot virus* (TRSV) ve *Tomato ringspot virus* (ToRSV) enfeksiyonları da görülmektedir (Moury ve ark., 2001; Szyndel ve ark., 2006).

Konya İlinde Gül Yetiştiriciliği İçin Öneriler

Konya park ve bahçelerindeki güllerin düzenli olarak virüs belirtileri açısından izlenmesi gereklidir. DAS-ELISA gibi güvenilir test yöntemleriyle erken teşhis sağlanmalı, özellikle solgunluk, yaprak deformasyonları ve çiçek kalitesindeki düşüşler gibi belirtiler dikkate alınmalıdır. Virüs yayılımını kontrol altına alabilmek için yılda en az iki kez (ilkbahar ve sonbahar) sürvey çalışmaları yapılması önerilir.

Bitki virüsleri çoğunlukla enfekte bitkilerle temas eden araçlar veya budama aletleri ile yayılabilmektedir. Tüm ekipmanların kullanım öncesi ve sonrası dezenfekte edilmesi önerilir. Bulaşık bitkilerin belirlenmesi durumunda, bu bitkiler diğer sağlıklı bitkilerden izole edilmeli ve mümkünse imha edilmelidir. PNRSV ve ApMV'ye karşı dayanıklı gül çeşitleri tercih edilmelidir. Virüslere karşı dirençli türlerin seçilmesi, yaygın virüs hastalıklarının etkilerini azaltabilir. PNRSV ve APMV'ye karşı dirençli veya toleranslı gül çeşitlerinin seçimi, hastalıklarla mücadelede önemli bir faktördür (Tan ve ark., 2022).

Gül fidanlarının, virüs hastalıklarıyla bulaşık olmayan, sağlıklı kaynaklardan temin edilmesi gereklidir. Yeni fidanların, hastalık taşıyıcı olup olmadığını doğrulamak için test edilmesi tavsiye edilmektedir. Enfekte olduğu belirlenen bitki materyalinin derhal imha edilmesi, virüslerin yayılmasını önlemede etkili bir stratejidir (Şimşek ve ark., 2010).

Virüslerin doğrudan tedavisi mümkün olmadığından, virüs taşıyan vektörlerin kontrolü önemlidir. Uygun insektisit ve akarisitlerle vektör kontrolü sağlanmalıdır.

Park ve bahçelerde çalışan personelin, virüs hastalıkları konusunda eğitilmesi ve hastalıklarla bulaşık bitkileri tanımlayabilmeleri için bilgilendirilmesi gereklidir.

Bu adımlar, Konya'da gül yetiştiriciliğinin daha sağlıklı ve sürdürülebilir bir şekilde yapılmasına yardımcı olabilir. Erken teşhis, bilinçli yönetim ve doğru çeşit seçimi, virüs hastalıklarının etkilerini önemli ölçüde azaltacaktır.

Beyan

Bu çalışma 7. Uluslararası Anadolu Tarım, Gıda, Çevre ve Biyoloji Kongresi'nde (Kastamonu, TARGİD 2024) sunulmuştur.

Bilgi

Bu çalışma, Adile Tuğç ORHAN'ın "Konya İlinde Gül (*Rosa* spp.) Bitkisinde Enfeksiyon Oluşturan Erik Nekrotik Halkalı Leke Virüsü (PNRSV) ve Elma Mozaik Virüsü (ApMV)'nün Varlıklarının Belirlenmesi" isimli Yüksek Lisans Tezi'nden üretilmiştir. Yazarlar herhangi bir çıkar çatışması olmadığını belirtmektedir.

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Frozen Food Consumption Habits of Working Women

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ABSTRACT

The aim of this study was to evaluate the frozen food consumption habits of working women in 19 Mayıs district of Samsun province. The study was conducted with 200 working women. Actively working individuals who volunteered to participate in the study were included in the study. Body weight and height of the individuals were measured. Body mass index (BMI) was calculated using body weight and height. In the results of the study, 76.0% of the individuals consumed frozen foods while 24.0% did not. Among the frozen food groups, meat and meat products, fruits and vegetables, and pastries are consumed more, respectively. The reasons for purchasing frozen foods were as follows: 41.4% of the individuals stated that they purchased frozen foods because of saving time, 48.0% because of ease of preparation, 6.6% because they were influenced by advertisements, and 18.4% because of seasonal differences. When the reasons why individuals do not buy it are analyzed, 25.0% find the price high, 33.3% believe that it is healthy, 33.3% state that it is not fresh and 4.2% think that it is not satisfying. When the type of consumption was analyzed, 61.8% stated that they consumed it as a side dish, 42.8% as an appetizer, and 17.1% as a main dish. Among family members, individuals between the ages of 15-30 consume frozen food the most. A statistically significant difference was found between the age, marital status, and education of the individuals participating in the study according to whether they consume frozen food or not. Overall, frozen foods can be a convenient and practical option for working individuals and families, offering a balance between convenience, nutrition and taste. However, it is necessary to pay attention to safe labeling, storage conditions, amount and method of consumption of frozen foods.

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Çalışan Kadınların Dondurulmuş Besin Tüketim Alışkanlıkları

MAKALE BİLGİSİ

Araştırma Makalesi

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Çalışan kadın
Dondurulmuş besin
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Tutum ve davranış
Beslenme

ÖZ

Bu çalışmada, Samsun ili 19 Mayıs ilçesinde çalışma hayatında yer alan kadınların dondurulmuş besin tüketim alışkanlıklarının değerlendirilmesi amaçlanmıştır. Araştırma, 200 çalışan kadın birey ile yapılmıştır. Aktif olarak çalışan ve araştırmaya katılmaya gönüllü olan bireyler çalışmaya dahil edilmiştir. Bireylerin vücut ağırlığı ve boy uzunluğu ölçülmüştür. Bireylerin vücut ağırlığı ve boy uzunluğu kullanılarak beden kütle indeksi (BKİ) hesaplanmıştır. Araştırma sonuçlarında, bireylerin %76,0'sı dondurulmuş besin tüketirken %24,0'ü tüketmemektedir. Dondurulmuş besin gruplarından sırasıyla et ve et ürünleri, meyve ve sebze, hamur işleri daha fazla tüketilmektedir. Bireylerin dondurulmuş besin satın alma nedenleri, %41,4'nün zamandan tasarruf, %48,0'nin hazırlama kolaylığından, %6,6'nın reklamlardan etkilendiği, %18,4'nün mevsimsel farklılıktan satın aldıklarını belirtmişlerdir. Bireylerin satın almama nedenleri incelendiğinde, %25,0'i fiyatını yüksek bulmakta, %33,3'ü sağlıklı olduğuna inanmakta, %33,3'ü taze olmadığı ifade etmekte ve %4,2'i ise doyurucu olmadığını düşünmektedir. Tüketim şekli incelendiğinde, %61,8'i yardımcı yemek olarak, %42,8'i aperatif olarak, %17,1'i ana yemek olarak tükettiklerini belirtmişlerdir. Aile bireyleri içerisinde 15-30 yaş aralığında bireyler dondurulmuş besini en fazla tüketmektedir. Araştırmaya katılan bireylerin dondurulmuş besin tüketip tüketmeme durumuna göre yaş, medeni durum, eğitimleri arasında istatistiksel olarak anlamlı bir farklılık bulunmuştur. Genel olarak dondurulmuş besinler, çalışan bireyler ve aileler için kolaylık, beslenme ve lezzet arasında bir denge sunan kullanışlı ve pratik bir seçenek olabilir. Ancak dondurulmuş besinlerin güvenli etiketlemeye, depolama koşullarına, tüketim miktarına ve şekline de dikkat etmek gerekmektedir.

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Giriş

Dünyadaki ekonomik, sosyal ve kültürel gelişmeler toplum hayatında değişmelere neden olmaktadır. Bu gelişmelerle birlikte bireylerin beslenme ve tüketim alışkanlıkları da zamanla değişmektedir. Hazır dondurulmuş besinler, servis edilmeden önce sadece ısıtılmaya ihtiyaç duyan, önceden paketlenmiş, taze veya dondurulmuş yemeklerdir. Bu tür besinler soğuk sıcaklıkta saklanmaktadır. Aynı zamanda uygun ambalajda satılan ve kullanıma hazır besinlerdir. Güvenlik kılıfı ile kaplanmış olmalıdır. Üretim tarihi ve son kullanma tarihi paketin üzerinde yer almalıdır. Dondurulmuş besinler genellikle dondurulmadan önce kullanım için kısmen pişirilmiş, daha sonra paketlenmiş ve hızlı bir şekilde saklanmıştır. Ortam şartları besinlerin hızlı bozulmasına mikrobiyal büyümenin ve biyokimyasal reaksiyonların tetiklenmesine neden olmaktadır (Coulomb, 2008). Bu nedenle besinlerin daha iyi muhafaza edilebilmesi için soğutma, kurutma, dondurma gibi yöntemler geliştirilmiştir. Bunların arasında dondurma tekniği besinlere daha uzun raf ömrü sağlamaktadır. Dondurulmuş besinlerde serbest suyun katılaşması nedeniyle patojen mikrobiyallerin büyümesi ve biyokimyasal reaksiyonu engellenmekte ve bu da besinin yavaş bozulmasına neden olmaktadır. Ancak dondurulmuş besinler dondurulma, dondurularak saklama ve sonrasında çözdürme sırasında da bazı yapısal değişikliklere uğramaktadır (Zhu ve ark., 2020). Genellikle yavaş dondurma, hücrelerin dışında büyük ve eşit olmayan şekilde dağılmış buz kristalleri üreterek ciddi donma hasarına yol açmaktadır. Hızlı dondurma, hücre içi ve hücre dışı alanda sıklıkla ince ve homojen bir şekilde dağılmış buz kristalleri oluşturarak donma hasarının etkili bir şekilde hafifletilmesine yol açmaktadır. Tekrarlanan donma-çözülme döngüleri de büyük ölçüde buz kristalleşmesi nedeniyle gıda ürünlerinin kalitesini etkilemektedir ve yeniden kristalleşme, beklenmedik mekanik hasara neden olmakta dokulara ve hücre yapısına zarar vermektedir (Chen ve ark., 2020). Besinlerin dondurma işlemi, en kolay ve en etkili besin koruma yöntemlerinden biridir. Genellikle ek işlem gerektirmeyen bir yöntemdir. Dondurulacak meyve ve sebzeler genellikle en yüksek olgunlukta hasat edilir ve dondurulur. Sebzeler genellikle dondurulmadan önce hafif haşlanır. Haşlama, sebzelerdeki lezzet, renk, doku ve besin kaybına neden olacak enzimleri etkisiz hale getirmek için yapılır. Meyvelerde donmadan önce haşlama gerektirmez. Bunun yerine rengi korumak ve kızarmayı önlemek için askorbik asit eklenmektedir. En yaygın olarak muz ve şeftalide yapılmaktadır (Li ve ark., 2017). Dondurulmuş besinler batılılaşmanın etkisi ile ortaya çıkmıştır. Küreselleşmenin hızlanması ile beraber bireyler meslekleri ile daha fazla zaman harcamaya başlamıştır. Kültür de aynı şekilde küreselleşmeye uyum sağlamak için değişmiştir. Genel olarak bireylerin yaşam biçimleri büyük ölçüde değişmiştir. Kadınların çalışma hayatına daha fazla girmesi ile beraber eve ayırdıkları zaman azalmıştır. Bu yüzden yapması kolay, temiz, hijyenik ve çalışma hayatlarına zaman kazandıran bu tür yiyeceklere ihtiyaç duymaktadırlar. Hazır dondurulmuş besinler bu türden bir üründür (Sen ve ark, 2021). Ayrıca, yaşam tarzındaki değişimin hızı ve evlilikle birlikte bireyler hazır dondurulmuş besinlere yönelmeye başlamıştır. Hintli ailelerin %70,0'ı çekirdek ailelerden oluşmaktadır ve kadınlar yemek pişirmek için daha az enerji harcamak istemektedirler (Mohan ve Gill, 2013). Tek başına yaşayan, eşinden ayrılmış kadınların beslenme düzeni ailesiyle yaşayan kadınlardan farklıdır. Tek başına yaşayan kadınların büyük kısmı farklı türde yemek hazırlama yöntemleri kullanmaktadırlar. Bunun nedeni, iş yükü, besin alımı isteksizliği olabilmektedir. Bu yüzden hazır dondurulmuş besinlere ilgi artmaktadır. Evde tüketilen hazır besinlerin büyük çoğunluğu dondurulmuş besinlerden oluşmaktadır. Kolay hazırlanması, zamandan tasarruf sağlaması, dolapta fazla yer tutmaması, besin değerini koruması dondurulmuş besin tüketimini arttıran önemli faktörlerdendir (Muktawat ve Vama, 2013). Ayrıca kolaylık, görünüm, tat ve doku gibi nedenlerde hazır dondurulmuş besin tüketim nedenleri arasındadır (Patel ve Rathod, 2017). Çalışmalar, bireylerin hazır dondurulmuş besin satın alma nedenleri hakkında net bir fikir vermektedir. Bazı farklı nedenler ve faktörler belirtilmektedir. Bireylerin bir ürünü satın almasını etkileyen faktörleri belirleme alanında birçok çalışma bulunmaktadır. Ancak hazır dondurulmuş besin bağlamında araştırmacılar tarafından yapılan çok sınırlı çalışma bulunmaktadır. Yapılan araştırmalarda, bireylerin satın alma amacını etkileyen üç tür değişken olduğu tespit edilmiştir. Bunlardan ilki algılanan değer, kalite ve üründen duyulan memnuniyeti içeren içsel unsurlardır. İkincisi fiyatlandırma, reklam, markalaşma, ambalajlama, bulunabilirlik vb. unsurları içeren dışsal değişkenlerdir. Sonuncusu ise bireylerin yaşı, mesleği, cinsel yönelimi, evlilik durumu, aile durumu, eğitimi ve benzerlerini içeren demografik bilgilerdir (Jaafer ve ark., 2012). Bireylerin büyük çoğunluğu hazır besin alışverişi için marketleri kullanmaktadır. Yaklaşık %66.0'ı genel mağazaları, geri kalanı ise yakınlardaki dükkanları kullanmaktadır. Süpermarketler ve mahalle dükkanları hazır dondurulmuş besin alışverişinde önemli bir rol oynamaktadır (Sen ve ark., 2021). Bu çalışmada, bireylerin dondurulmuş besin tüketimine ilişkin bilgileri, satın alma davranışları, dondurulmuş besinlere ilişkin davranış ve tutumları ve dondurulmuş besin tüketimini etkileyen faktörleri ortaya koymak amaçlanmıştır.

Materyal ve Yöntem

Araştırma Samsun ili 19 Mayıs ilçesinde bulunan toplam 200 kadın birey ile yapılmıştır. Bu araştırmanın örneklemini belirlemek amacıyla yapılan power analizi sonucuna göre %95 güven aralığında en az 200 çalışan kadına ulaşılması hedeflenmiştir (Murphy ve ark., 2004). Etik kurul komisyonundan 16.04.2024 tarihinde, 01-35 sayılı etik kurul izni alınmıştır. Araştırmanın evrenini çalışma hayatında yer alan kadınlar oluşturmuştur. Aktif olarak çalışan ve araştırmaya katılmaya gönüllü olan bireyler çalışmaya dahil edilmiştir. Araştırmanın verileri bireylerin kendi kendilerine cevap verebilecekleri anket formları ile toplanmıştır. Anketler araştırmacı eşliğinde çıktı alınmış formlarla toplanmıştır. Anket formunda bireylerin sosyo-demografik özelliklerini içeren sorular, dondurulmuş besin tüketimine ilişkin bilgiler, dondurulmuş besin satın alma şekli ve satın alıp-almama nedenleri, dondurulmuş besin tüketim zamanı

ve sıklığı, bireylerin dondurulmuş besinlere karşı davranış ve tutumları sorulmuştur. Bireylerin vücut ağırlığı ve boy uzunluğu ölçülmüştür. Bireylerin vücut ağırlığı ve boy uzunluğu kullanılarak beden kütle indeksi (BKİ) hesaplanmıştır. Bireylerin BKİ= Ağırlık (kg)/Boy $(m)^2$ formülü ile hesaplanıp, Dünya Sağlık Örgütü sınıflamasına göre değerlendirilmiştir. Beden kütle indeksi 18,50 kg/m^2'nin altında olanlar zayıf, 18,50–24,99 kg/m kg/m^2 arasında olanlar normal, 25.0–29,99 kg/m2 arasında olanlar fazla kilolu, 25,0–29,99 kg/m2 olanlar obez olarak sınıflandırılmıştır.

Verilerin İstatistiksel Değerlendirmesi

Araştırmanın istatistiksel analizinde SPSS 25.0 (Statistical Package For Social Sciences) paket programı kullanılmıştır. İstatistiksel analizde veriler tanımlayıcı değerler, aritmetik ortalama ± standart sapma, minimum, maksimum, frekans ve (%) olarak ifade edilmiştir. Kategorik değişkenlerde bağımsız iki veya daha fazla grup karşılaştırılırken Ki-kare Testi kullanılmıştır (Güngör, 2008). Elde edilen analiz sonuçları %95'lik güven aralığında $p<0,05$ ve $p<0,10$ anlamlılık düzeyinde değerlendirilerek yorumlanmıştır. Ayrıca, bireylerin dondurulmuş besine ilişkin tutum ve davranışlarını belirlemek için 5'li likert ölçeği kullanılmıştır (Coulomb, 2008).

Bulgular

Bireylerin Sosyo-Ekonomik ve Demografik Özellikleri

Bu araştırma yaşları 19-62 aralığında olan ve Samsun ili 19 Mayıs ilçesinde bulunan toplam 200 kadın katılımcı ile gerçekleştirilmiştir. Katılımcıların sosyo demografik özellikleri Çizelge 1'de verilmiştir. Çizelge 1'de ankete katılan bireylerin sosyo-ekonomik ve demografik özellikleri verilmiştir.

Çizelge 1. Bireylerin Sosyo Demografik Özellikleri
Table 1. Socio-Demographic Characteristics of Individuals

Özellik	n	%
Yaş (yıl)		
19-25	43	21,5
26-40	117	58,5
41-54	32	16,0
55 +	8	4,0
Toplam	200	100
Eğitim		
İlköğretim	37	18,5
Ortaöğretim	75	37,5
Önlisans	38	19,0
Lisans	40	20,0
Lisansüstü	10	5,0
Toplam	200	100
Medeni Durum		
Evli	128	64,0
Bekar	72	36,0
TOPLAM	200	100
Mesleki Dağılımları		
Memur	69	34,5
Esnaf	31	15,5
İşçi	73	36,5
Serbest	27	13,5
TOPLAM	200	100
Eşlerin Yaş Dağılımları (yıl)		
26-40	72	56,2
41-55	44	34,4
56 +	12	9,4
Toplam	128	100
Eşlerin Mesleki Dağılımları		
Memur	54	42,2
Esnaf	30	23,4
İşçi	12	9,4
Emekli	12	9,4
Serbest	20	15,6
Toplam	128	100
Aylık Ortalama Gelir		
5.000-15.000	8	4,0
16.000-30.000	83	41,5
31.000-45.000	50	25,0
46.000 +	59	29,5
Toplam	200	100

Çizelge 2. Dondurulmuş Besin Tüketimine İlişkin Bilgiler
Table 2. Information on Frozen Food Consumption

Bilgiler	n	%
Dondurulmuş besin hakkında bilgi sahibi olma durumu		
Var	198	99,0
Yok	2	1,0
Toplam	200	100
Dondurulmuş besin tüketme durumu		
Tüketen	152	76,0
Tüketmeyen	48	24,0
Toplam	200	100
Aylık gelirden dondurulmuş besine ayrılan miktar		
(0-500 tl)	27	17,7
(501-1000 tl)	46	30,3
(1001-1500 tl)	30	19,7
(1500 +)	49	32,3
Toplam	152	100
Dondurulmuş Besin Grupları İçerisinde En Çok Hangisini Tüketme Durumu		
Hamur işleri	66	43,4
Meyve ve Sebze	63	41,4
Et ve et ürünleri	69	45,5

*Birden fazla cevap verildiği için toplam %100 aşmaktadır.

Araştırmaya katılan bireylerin %18,5 ilköğretim mezunu, %20,0'si lisans mezunudur. Bireylerin %64,0'ü evli, %36,0'ı bekardır. Meslek gruplarına göre dağılım incelendiğinde, %34,5'u memur, %15,5'u esnaf, %36,5' u işçi, %13,5'u serbest çalışan olduğu belirlenmiştir. Aylık ortalama gelirleri incelendiğinde, %41,5'nun 16.000-30.000 olduğu, %29,5'nun 46.000'nin üzerinde olduğu saptanmıştır.

Araştırmaya katılan bireylerin %99,0'u dondurulmuş besin hakkında bilgi sahibi olduğunu belirtmiştir. Bireylerin %76,0'sı dondurulmuş besin tüketirken %24,0'ü tüketmemektedir. Dondurulmuş besin gruplarından hangisinin daha fazla tüketildiği incelendiğinde, %45,5'nin et ve et ürünleri, %41,4'nün meyve ve sebze, %43,4'nün hamur işleri olduğu saptanmıştır.

Katılımcıların dondurulmuş besin satın alma şekli ve satın alıp-almama nedenlerine, tüketim zamanı ve sıklığına ilişkin bilgiler Çizelge 3'te verilmiştir. Araştırmaya katılan bireylerin %80,9'nun dondurulmuş besinleri hem satın aldığı hem de evde hazırladığı, %33,6'sının sadece satın aldığı, %15,1'nin evde hazırladığı belirlenmiştir. Dondurulmuş besin satın alma nedenleri incelendiğinde, %41,4'nün zamandan tasarruf, %48,0'nin hazırlama kolaylığından, %6,6'nın reklamlardan etkilendiği, %18,4'nün mevsimsel farklılıktan satın aldıklarını belirtmişlerdir. Bireylerin satın almama nedenleri incelendiğinde, %25,0'i fiyatını yüksek bulmakta, %33,3'ü sağlıklı olduğunu düşünmemekte, %33,3'ü taze olmadığı düşünmekte ve %4,2'i doyurucu olmadığını düşünmektedir. Dondurulmuş besinin ev ortamında hazırlama nedeni incelendiğinde, %75,3'ü temiz olduğunu belirtmiştir. Araştırmaya katılan bireylerin %38,2'i yoğun zamanlarda, %32,9'u ani misafir geldiğinde, %42,8'i herhangi bir zamanda tükettiklerini belirtmişlerdir. Tüketim şekli incelendiğinde, %61,8'i yardımcı yemek olarak, %42,8'i aperatif olarak, %17,1'i ana yemek olarak tükettiklerini belirtmişlerdir. Tüketim sıklığı incelendiğinde, %76,9'nun haftada birkaç kez, %43,4'nün ayda bir, %2,6'nın günlük tükettiği belirlenmiştir. Aile bireyleri içerisinde 15-30 yaş aralığında bireyler dondurulmuş besini en fazla tüketmektedir. Araştırmaya katılan bireylerin, dondurulmuş besin satın alma yerleri incelendiğinde, %59,9'nun süpermarketten, %56,6'nın marketten, %8,6'nın bakkaldan, %5,3'nün toptancıdan aldığı belirlenmiştir. Besin satın alan aile bireyleri incelendiğinde, %46,7'nin anne baba birlikte aldıkları belirlenmiştir. Katılımcıların dondurulmuş besinlere ilişkin davranış ve tutumlarına ilişkin bilgiler Çizelge 4'de verilmiştir. Araştırmaya katılan bireylerin dondurulmuş besinlere ilişkin davranış ve tutumları incelendiğinde likert ölçeğine göre, dondurulmuş besinlerin kilo aldırdığını, zararlı katkı maddeleri bulunabileceğini, besinlerin tat değişikliğine uğradığını ve insan sağlığını olumsuz etkilediğini belirtmişlerdir.

Katılımcıların dondurulmuş besin tüketimini etkileyen faktörlere ilişkin bilgiler Çizelge 5'te verilmiştir. Araştırmaya katılan bireylerin dondurulmuş besin tüketip tüketmeme duruma göre yaş, medeni durum, eğitimleri arasında istatistiksel olarak anlamlı bir farklılık bulunmuştur. Kadınların ortalama BKİ değerleri 25,73±4,18 olup, %54,6'unun normal BKİ değerlerine sahip olduğu saptanmıştır.

Tartışma

Bu çalışmada, çalışma hayatında yer alan kadınların dondurulmuş besin tüketim alışkanlıkları incelenmiştir. Çalışan kadınların büyük bir kısmı dondurulmuş besin tüketmektedir. Büyük bir kısmı haftada birkaç kez akşam öğününde tükettiklerini belirtmişlerdir. Zamandan tasarruf sağladığını ve hazırlama kolaylığı olduğunu belirtmişlerdir. Davranış ve tutumlarına bakıldığında, kilo aldırdığını, zararlı katkı maddeleri bulunabileceğini, besinlerin tat değişikliğine uğradığını ve insan sağlığını olumsuz etkilediğini düşündüklerini belirtmişlerdir.

Çizelge 3. Dondurulmuş Besin Satın Alma Şekli ve Satın Alıp-Almama Nedenleri Tüketim Zamanı ve Sıklığı
Table 3. Purchase Methods of Frozen Food and Reasons for Purchasing or Not Purchasing, Consumption Time and Frequency

Bilgiler	n	%*
Dondurulmuş Besin Satın Alma veya Evde Hazırlama Durumu		
Satın alan	51	33,6
Evde Hazırlayan	23	15,1
Hem satın hem evde	123	80,9
Dondurulmuş Besin Satın Alma Nedeni		
Zamandan tasarruf	63	41,4
Hazırlama kolaylığı	73	48,0
Reklamların etkisi	10	6,6
Mevsimsel Farklılık	28	18,4
Dondurulmuş Besin Satın Almama Nedeni		
Fiyatı yüksek	28	25,0
Sağlıklı değil	32	33,3
Taze değil	19	33,3
Doyurucu değil	13	4,2
Dondurulmuş Besini Ev Ortamında Hazırlama Nedeni		
Ucuz olması	46	31,5
Temiz olması	110	75,3
İhtiyaç kadar olması	120	82,2
Dondurulmuş besin tüketim zamanları		
Fark etmiyor	65	42,8
Yoğun zaman	58	38,2
Ani misafir	50	32,9
Dondurulmuş besin tüketim şekli		
Ana yemek	26	17,1
Yardımcı yemek	94	61,8
Aperatif	65	42,8
Dondurulmuş Besinleri En Çok Hangi Öğünde Tükettiği		
Sabah	3	1,9
Öğle	10	6,6
Ara Öğün	27	17,8
Akşam	112	73,7
Dondurulmuş Besin Tüketim Sıklığı		
Günlük	4	2,6
Haftada birkaç kez	117	76,9
Ayda bir	66	43,4
Daha seyrek	11	7,2
Aile Bireyleri İçinde En Çok Hangi Yaş Aralığının Tükettiği		
<15	9	5,9
15-30	102	67,1
31-50	82	53,9
50 +	5	3,3
Dondurulmuş Besin Satın Alma Yerleri		
Bakkal	13	8,6
Market	86	56,6
Süpermarket	91	59,9
Toptancı	8	5,3
Besin satın alan aile bireyleri		
Anne	32	21,0
Baba	29	19,1
Yetişkin Çocuklar	20	13,2
Anne baba birlikte	71	46,7

*Birden fazla cevap verildiği için toplam %100 aşmaktadır.

Ankara'da çalışan ve çalışmayan kadınlar ile yapılan bir çalışmada, dondurulmuş besinleri satın alma, hazırlama ve pişirme konusundaki bilgi ve davranışları incelenmiştir. Kadınların büyük bir çoğunluğunun et ürünlerini ambalajsız süt ve peyniri ise ambalajlı aldığı saptanmıştır. Çalışan ve çalışmayan kadınların kırmızı et, tavuk-hindi, salam, sosis, sucuk ve sütü ambalajlı veya ambalajsız satın alma durumları arasındaki farklılık önemli bulunmuştur. Çalışmaya katılan bireylerin %13,1'inin dondurulmuş besin satın aldığı, %70,2'sinin satın almadığı, %16,7'sinin ise bazen satın aldığı belirlenmiştir (Ayaz ve Bilici, 2008). Bu çalışmada, bireylerin %76'sı dondurulmuş besin tüketirken %24'ü tüketmemektedir.

Çizelge 4. Dondurulmuş besinlere ilişkin bireylerin tutum ve davranışları
Table 4. Attitudes and behaviors of individuals towards frozen foods

Sorular		1	2	3	4	5	Ortalama Puanı
İnsan sağlığını olumsuz etkiler	n	2	39	33	94	32	3,57
	%	1,0	19,5	16,5	47,0	16,0	
Kilo aldırır	n	3	33	41	78	45	3,64
	%	1,5	16,5	20,5	39,0	22,5	
Kansere yol açar	n	2	43	82	62	11	3,18
	%	1,0	21,5	41,0	31,0	5,5	
Zararlı katkı maddeleri bulunur	n	1	19	46	123	11	3,62
	%	0,5	9,5	23,0	61,5	5,5	
Tat değişikliğine uğrar	n	6	23	44	102	25	3,58
	%	3,0	11,5	22,0	51,0	12,5	
Aile bütçesine katkı sağlar	n	24	46	82	44	4	2,79
	%	12,0	23,0	41,0	22,0	2,0	
Aile bütçesine sorumlulukları olumlu etkiler	n	28	41	74	53	4	2,82
	%	14,0	20,5	37,0	26,5	2,0	

1.Kesinlikle katılmıyorum 2.Katılmıyorum 3. Kararsızım 4. Katılıyorum 5. Kesinlikle katılıyorum

Çizelge 5. Dondurulmuş Besin Tüketimini Etkileyen Faktörler
Table 5. Factors Affecting Frozen Food Consumption

Faktörler		Dondurulmuş Besin				χ^2	p	DF
		Tüketenler		Tüketmeyenler				
		n	%	n	%			
Yaş (yıl)	19-25	29	67,4	14	32,6	10,67	0,01*	3
	26-40	85	72,6	32	27,4			
	41-54	31	96,9	1	3,1			
	55 +	7	87,5	1	12,5			
Gelir (TL)	5000-15.000	5	62,5	3	37.5	1,15	0,76	3
	16.000- 30.000	65	78,3	18	21,7			
	31.000- 45.000	37	74,0	13	26,0			
	> 46.000	45	76,3	14	23,7			
Medeni durum	Evli	102	79,7	26	20,3	2,65	0,10**	1
	Bekar	50	69,4	22	30,6			
Eğitim	İlköğretim	33	89,2	4	10,8	8,09	0,08**	4
	Ortaöğretim	54	72	21	28			
	Önlisans	30	78,9	8	21,1			
	Lisans	26	65	14	35			
	Lisansüstü	9	90	1	10			
Meslek	Memur	54	78,3	15	21,7	3,01	0,38	3
	Esnaf	25	80	6	20			
	İşçi	57	78,1	16	21,9			
	Serbest	17	63	10	37			
BKİ(kg/m^2)	<18,5	5	3,3	6	12,5	0,52	0,34	3
	18.5-24.9	83	54,6	27	56,3			
	25-29.9	60	39,5	15	31,2			
	≥30	4	2,6	0	0			

BKİ (Beden Kütle İndeksi) *p < 0,05 ** p < 0,10

Çalışan kadınların % 71,1'i, çalışmayan kadınların ise %44,8 'i donmuş ürünlerden hamur işlerini tercih etmektedir. Bu çalışmada, dondurulmuş besin gruplarından hangisinin daha fazla tüketildiği incelendiğinde, %45,5'nin et ve et ürünleri, %41,4'nün meyve ve sebze, %43,4'nün hamur işleri olduğu saptanmıştır.

Ankara'da farklı sosyo-ekonomik düzeye sahip kadınların dondurulmuş hazır besinleri saklama, kullanma ve evde besinleri dondurma durumlarının saptanması amacıyla yapılan bir araştırmada, dondurulmuş hazır besinleri en fazla yüksek sosyo-ekonomik düzeyde olan, çalışan kadınların kullandığı, dondurulmuş besinlerden en fazla meyve, sebze, beyaz et ve hamur işlerinin tercih edildiği saptanmıştır (Arıkan ve Şanlıer, 2000). Dondurulmuş besin tercihleri bizim çalışmamızda da en fazla et, meyve ve sebze, hamur işleridir. Sosyo-ekonomik düzeylerine bakıldığında, dondurulmuş besin tüketimi olan bireylerin %29,5'nun sosyo ekonomik düzeyi yüksektir.

Üniversite öğrencilerinin dondurulmuş besin tüketim alışkanlıklarının incelendiği bir çalışmada, üniversite öğrencilerinin %92,1 oranında dondurulmuş besin tükettiği bulunmuştur. Tüketim nedenlerine bakıldığında pratik olması önemli bir etken olarak belirtilmiştir (Yıldız, 2019). Bu çalışmada da, çalışan kadınların %48'i hazırlama kolaylığından dolayı tercih ettiklerini belirtmişlerdir.

Üniversite öğrencileri dondurulmuş besin tüketerek sağlıksız beslendiklerini belirtmişlerdir. Bu çalışmada da, davranış ve tutumlara bakıldığında bireyler dondurulmuş besinlerin kilo aldırdığını belirtmiştir. Aynı zamanda %33,3'ü sağlıklı olmadığını düşünmektedir. Yapılan bir çalışmada, dondurulmuş besin tüketimini etkileyen sosyoekonomik özelliklerin belirlenmesi amaçlanmıştır.

Erzurum ilinde 336 aileyle yaptıkları araştırmada elde ettikleri bulgulara göre, dondurulmuş besin tüketiminin gelir düzeyiyle orantılı olduğu sonucu ortaya çıkmıştır. Bu durum, yüksek gelirli ailelerin düşük gelirli ailelere göre dondurulmuş besin tüketme olasılığının daha yüksek olduğunu göstermektedir. Gelir düzeyi ile dondurulmuş besin tüketimi arasındaki ilişkinin yanı sıra eğitim düzeyi yüksek bireylerin, eğitim düzeyi düşük olanlara göre dondurulmuş besin tüketmeye daha yatkın olduğu belirtilmiştir. Ayrıca ailedeki kişi sayısı arttıkça dondurulmuş besin tüketiminin azaldığını da gözlemlemişlerdir. Dondurulmuş besinlerin bireyler tarafından algılanan en önemli özelliklerinden biri kolaylık ve zaman tasarrufu sağlamasıdır (Külekçi ve ark, 2006). Bu çalışmada, gelir ve eğitim düzeyi arttıkça tüketim miktarı artmamaktadır. Fakat gelir ve eğitim düzeyi yüksek kişiler, dondurulmuş besinleri daha fazla tercih etmektedir. Aynı zamanda bu çalışma ile uygun olarak bireylerin %41,4'ü zamandan tasarruf ettiği için dondurulmuş besin satın aldıklarını belirtmiştir.

Dondurulmuş besin tüketimini etkileyen sosyo-ekonomik faktörleri araştırmak amacıyla Akdeniz Üniversitesi'nde görev yapan öğretim üyelerinin dondurulmuş besin tüketim alışkanlıklarını inceleyen araştırmada, dondurulmuş besin tüketimi artışı ile yüksek gelir ve eğitim düzeyi arasında bir ilişki olduğu tespit edilmiştir. Bu bulgu bireylerin gelir ve eğitim düzeyleri arttıkça dondurulmuş besin tüketme olasılıklarının arttığını göstermektedir (Demirel, 2017). Samsun'da 185 aile bireyi üzerine yapılan bir çalışmada, ailelerin %82'si dondurulmuş besin tükettiğini bildirmiştir. Dondurulmuş besin tüketim sıklığını etkileyen çeşitli sosyo-ekonomik faktörler bulunmuştur. Bunlar arasında ailedeki kişi sayısı, eşin yaşı, ailenin gelir düzeyi ve çalışma durumu belirtilmiştir. Sağlık, fiyat ve dondurulmuş besinlerin algılanan zaman tasarrufu özelliği gibi davranışsal faktörler de ankete katılan aileler arasında dondurulmuş besin tüketim sıklığının belirlenmesinde önemli bir rol oynamıştır. Bu bulgular, dondurulmuş besin tüketimine ilişkin tüketici tercihlerini ve alışkanlıklarını şekillendirmede sosyo-ekonomik ve davranışsal faktörler arasındaki karmaşık etkileşimi vurgulamaktadır (Gündüz ve Emir, 2010). Bu çalışmada, bireylerin %76'sı dondurulmuş besin tükettiğini bildirmiştir.

Eşlerin mesleki dağılımına bakıldığında %42,2'i memurdur. Eşlerin yaş aralığı 26-40 aralığındadır. Ailenin gelir düzeyi ile anlamlı bir ilişki bulunmamıştır. Kültürel farklılıkların dondurulmuş besin tüketim alışkanlıklarına etkisi üzerine yapılan araştırmada, ülkedeki tüketicilerin %35,3'ünün haftada bir defadan fazla dondurulmuş besin satın aldığını belirtmiştir. Bu bulgu, nüfusun önemli bir kısmının dondurulmuş besinleri düzenli alışveriş alışkanlıklarına dahil ettiğini ve kültürel bağlamda dondurulmuş besinlerin nispeten yüksek düzeyde kabul edildiğini ve tüketildiğini göstermektedir (Korkmaz, 2011). Bu çalışmada, bireylerin %76.9'u dondurulmuş besini haftada birkaç kez tükettiklerini belirtmişlerdir.

Tüketicilerin dondurulmuş besin tüketim alışkanlıklarının incelenmesi amacıyla Adana ili merkez ilçelerinde gerçekleştirilen araştırmada, ankete katılan 372 kişiden %89,2'sinin dondurulmuş besin tükettiği belirlenmiştir. Bireylerin yaklaşık %81,84'ü dondurulmuş besin satın aldığını bildirmiştir. Ankete katılanların yaklaşık %77,65'i dondurulmuş besinleri evde hazırladığını belirtmiştir. Bu bulgular, Adana ilinde ankete katılan nüfus arasında dondurulmuş gıda tüketiminin yüksek bir prevalansa sahip olduğunu göstermektedir. Bu bulgular, dondurulmuş besinlerin yaygın bir şekilde kabul edildiği sonucunu çıkarmaktadır (Özer, 2013). Bu çalışmada, evde hazırlayanların oranı %15,1, hem evde hazırlayan hem de satın alanların oranı %80,9 olarak belirtilmiştir.

Bireylerin dondurulmuş besin tercihlerini incelemek amacıyla Isparta ilinde 270 aileyle yapılan araştırmada, dondurulmuş besin satın alan bireyler üzerinde zaman tasarrufu, hazırlama kolaylığı, her mevsim bulunabilirlik gibi faktörlerin oldukça etkili olduğu belirlenmiştir. Bu faktörler, tüketicilerin dondurulmuş besinlere yönelik tercihlerini yönlendirmede kolaylık ve erişilebilirliğin önemli rol oynadığını göstermektedir. Kişi başına düşen yıllık dondurulmuş besin tüketimi ürün gruplarına göre incelendiğinde sebze, et ve et ürünleri ve hamur işlerinin daha sık tüketildiği belirtilmiştir. Araştırmaya katılan bireyler ana yemek olarak dondurulmuş besin ürünlerini tercih ettiklerini belirtmişlerdir. Bu, dondurulmuş besinlerin yalnızca hızlı atıştırmalıklar veya garnitürler için uygun seçenekler olarak görülmediğini, aynı zamanda ana öğün olarak düzenli yemek rutinlerine entegre edildiğini göstermektedir (Yatağan ve ark., 2015). Bu çalışmada, dondurulmuş besin tüketimi ürün gruplarına göre incelendiğinde, sebze, et ve et ürünleri ve hamur işlerinin daha sık tüketildiği belirlenmiştir. Bireylerin %17,1'i dondurulmuş besinleri ana yemek olarak tükettiklerini bildirmişlerdir.

Sonuç ve Öneriler

Son yıllarda dondurulmuş besin tüketimi önemli artış göstermiştir. Pratik ve hijyen olması, kadınların çalışma hayatına daha fazla dahil olması gibi etkenler dondurulmuş besin tüketiminde önemli artış sağlayan hususlardan bazılarıdır. Meyve ve sebzelerden etlere, deniz ürünlerine, hazır yemeklere ve hatta tatlılara kadar çok çeşitli dondurulmuş besinler mevcuttur. Dondurulmuş besinler avantaj ve dezavantajlara sahiptir. Besinlerin dondurulması, taze besinlere kıyasla raf ömrünü önemli ölçüde uzatmaktadır. Dondurulmuş besinler genellikle önceden hazırlanır veya önceden pişirilir, bu da yemek hazırlamanın hızlı ve kolay olmasını sağlar. Uygun şekilde dondurulmuş besinler, özellikle hasattan veya hazırlandıktan kısa bir süre sonra dondurulursa, besin değerlerinin çoğunu koruyabilmektedir. Dondurma, tüketicilerin toplu olarak satın almalarına ve yalnızca ihtiyaç duydukları kadar kullanmalarına olanak tanıyarak gıda israfını azaltabilir. Dondurulmuş besinler, mevsimsel bulunup bulunmadığına bakılmaksızın yıl boyunca mevcut olabilir.

Donma ve çözülme bazen belirli besinlerin dokusunu etkileyerek onları daha az çekici hale getirebilir. Bazı yiyecekler uzun süre dondurulduklarında tat değişiklikleri yaşanabilir. Bazı dondurulmuş besinler, özellikle de hazırlanmış yemekler, lezzeti artırmak veya raf ömrünü uzatmak için ilave koruyucu maddeler, sodyum veya başka bileşenler içerebilir. Sonuçlarımızda özellikle bireylerin dondurulmuş besinlere olan davranış ve tutumları, eğitimi, yaşı ve medeni durumu tüketim alışkanlıklarında önemli bulunmuştur. Genel olarak dondurulmuş besinler, çalışan bireyler ve aileler için kolaylık, beslenme ve lezzet arasında bir denge sunan kullanışlı ve pratik bir seçenek olabilir. Bununla birlikte, herhangi bir besin seçiminde olduğu gibi, dondurulmuş besinleri beslenme programına dahil ederken besin içeriği, içindekiler listesi ve kişisel tercihler gibi faktörleri dikkate almak önemlidir. Aynı zamanda uygun depolama koşulları tat ve doku kaybını önlemek açısından önemlidir. Güvenli etiketlemeye, depolama koşullarına, tüketim miktarına ve şekline dikkat etmek gereklidir.

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- Verilerin sözel beyana dayalı alınması,
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- Bütçe desteğinin olmaması

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"Yazar çıkar çatışması beyan etmemektedir."

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Differential Antimicrobial Potential of *Ajuga integrifolia* Buch. Ham. Ex D.Don Based on Extraction Solvents

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ABSTRACT

The current study aimed to evaluate the effect of extraction solvents on the anti-bacterial and anti-fungal efficacy of the stem and roots of *Ajuga integrifolia* Buch. Ham. ex D. Extracts were prepared in different solvents and tested against fungi and bacteria species including, *Agrobacterium tumefaciens, Xanthomonos oryzae, Citrobacter freundi, Alternaria alternata, A. solani* and *Aspergillus niger.* Antibacterial efficacy of the *Ajuga integrifolia* was carried out by disc diffusion susceptibility method and antifungal efficacy by well diffusion susceptibility method. Methanol stem extract revealed efficacy against *C. freundi* by producing a 63% zone of inhibition at 3000µg/disc while methanol roots extract produced 77% ZI against *A. tumifaciens*. Methanol root and stem extracts produced an equal zone of inhibition (97%) at 1000 µg/ml concentration against *A. alternata* and *A. solani.* The results of the study clearly stated that the polarity of the solvents used in the extraction procedure affects the bioactivities of the extracts.

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Introduction

Medicinal flora is a gift of nature for humanity and produces large numbers of bioactive compounds that possess remarkable biological activities, such as pharmaceuticals, dyes, pesticides, flavors, and scents (Kına et al., 2021; Akgül et al., 2022). Medicinal plants produced antimicrobial components to protect plants against viruses, bacteria, and fungi (Vohra and Kaur, 2011; Krupodorova et al., 2022). Antimicrobial components possess the phytotherapeutic potential to cure wide verities of illnesses and ailments. Traditionally rural people used medicinal herbs in Ayurveda for curing their sicknesses (Rahman et al., 2015; Ahmadipour et al., 2016; Hussain et al., 2016; Mohammed et al., 2022; Unal et al., 2022). Fungi and bacteria have the abilities to show drug resistance that increase the rate of infections. Rapid increases in infections threaten human fitness, especially immune-compromised which needs rapid, modified, and accurate drugs (Fazal et al., 2012; Nasrullah et al., 2012). Medicinal plants are one of the important sources of bioactive compounds which can be used as an alternative to anti-microbial chemotherapy and used for the production of new medication (Farnaz et al., 2011; Walter et al., 2011; Mothana et al., 2012; Sevindik et al., 2017; Pehlivan et al., 2021; Uysal et al., 2021).

Pakistan has a rich of medicinal plants, including *Ajuga integrifolia* Wall ex. Benth has therapeutic potential. *A. integrifolia* leaves, stem, barks, roots, and flowers possess pharmacological properties such as anti-bacterial, anti-fungal, anti-parasitic, anti-tumor, anti-inflammatory, antipyretic, anti-malarial, immune-regulatory and cytotoxic (Pal et al., 2011; Jan et al., 2014 Hussain et al., 2016). The currents study was designed to evaluate the effect of extraction solvents on antibacterial and antifungal efficacy of *A. integrifolia* Wall ex. Benth against humans and plants pathogenic microorganisms.

Material and Method

Plant Material Collection and Identification

A. integrifolia was collected from the district Swat and taxonomically identified by Prof Dr. Zahid Khan University of Swat Khyber Pakhtunkhwa, Pakistan.

Chemicals and equipment used in experiments

All solvents used for extraction were analytical grade (Merck & Co., Inc., Kenilworth, NJ, USA). Nutrient agar and nutrient broth were purchased from Musaji Adam & Sons. Ciprofloxacin and Terbinafine were provided by Meditech Pharmaceuticals Peshawar. Whatman filter paper was used for filtration and a Rotary evaporator (Rotavapor R-R 210/R215; BUCHIL Labortechnik AG) for drying solutions.

Stem and Roots Crude Extract Preparation

Stem and roots were thoroughly washed and kept in the shade. Dry material is macerated to powder form. Five (5) and 2.5-liter methanol were added to the stem and root material respectively. The solution was filtered through Whatman filter paper No.1 and dried via a rotary evaporator and stored in a glass vial till used.

Stem and Roots Crude Extract Fractionation

The crude extract was weighted (52gm) and divided into two parts. One portion (10g) was kept in a glass vial and tested as a crude extract in antimicrobial efficacy while the other part (42 grams) was dissolved in three hundred mL of distilled water and poured into a Separatory funnel. The lower aqueous layer was collected first followed by hexane layers in separate flasks. The water fraction was re-extracted with 600mL more hexane. The same process was also applied to ethyl acetate and *n*-butanol. All the fractions were dried via a Rotary evaporator (Khan et al., 2017).

Preparation and Autoclaving of Culture Media

Nutrient agar and Nutrient broth were prepared according to standard procedure for antimicrobial bioassay. For fungal bioassay, potato dextrose media was prepared from 300g of potato extract, 20g of dextrose, 20g of agar, and 1L of water. Other accessories and media-containing bottles were autoclaved at 15psi for 15 minutes at 121°C. Media were poured into Petri plates under sterile conditions.

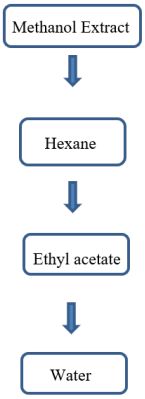

Figure 1. Solvents arranged in ascending order of polarity used in the fractionation of methanol extract

Anti-Fungal and Anti-Bacterial Bioassay

The anti-fungal and anti-bacterial bioassays were done by the well and disc diffusion method. Fungal species used in this study were *Alternaria alternata, Alternaria solani, Aspergillus niger* while the bacterial species were *Cirtrobacter feundii, xanthomonos oryzae*, *Agrobavterium tumefeciens* and *Bacillus subtilis.* The above strains were provided by the Department of Plant Pathology, the University of Agriculture Peshawar, and the Department of Microbiology University of Swat. Fungal strains were cultured on the potato dextrose agar and standardized on potato dextrose broth media while the bacteria were cultured on nutrient agar and standardized on nutrient broth media (Khan et al., 2016; Khan et al., 2017).

Statistical Analysis

The treatment applied to experimental units in triplicate and data were collected. The means and standard deviation of data were measured by the statistical software SPSS (v. 20.0 SPSS Inc., Chicago, IL, USA).

Results

Antibacterial Bioassay by Disk Diffusion Assay

Different solvent-extracted samples from the stem of *A. integrifolia* showed antibacterial potential against the tested microorganisms. Among the tested microorganisms the growth of *B. subtilis* was inhibited by crude methanol extracts and formed an equal zone of inhibition of 54% at 1000µg/disc, 2000µg/disc, and 3000µg/disc while *n*-butanol extracts showed 41% ZI at 1000µg/disc and produced equal ZI (48%) at 2000µg and 3000µg/disc. N-hexane fractions revealed an equal zone of inhibition of 33% at any concentration. Furthermore, ethyl acetate at 1000 and 2000µg concentration produced equal ZI (33%) while at 3000µg concentration revealed 48% ZI. Water stem extract showed 32%, 48%, and 51% ZI respectively at 1000, 2000, and 3000µg/disc. Hot-water stem extract did not show activity at any concentration level. Similarly, the root extracts of *A. integrifolia also* showed anti-*B. subtilis* activity. Crude methanol extract of roots produced 41%, *n*-butanol 63%, water fraction 48%, ethyl acetate 38%, and *n*-hexane 16% ZI at 1000µg/disc. Crude methanol and *n*-butanol produced an equal zone of inhibition (63% ZI) while *n*-hexane and water fraction revealed the same ZI 48% and ethyl acetate produced 41% ZI at 2000µg/disc. Methanol and *n*-butanol root extract showed equal ZI of 63% and *n*-hexane and water root extract showed the same zone of inhibition (54%) while ethyl acetate fraction showed 41% ZI at 3000µg/disc. The hot-water extract did not affect the growth of *B. subtilis* at any concentrations. The stem extracts showed antibacterial efficacy against *A. tumifacians*. Crude extract inhibited the growth of *A. tumifacian* by 59%, ethyl acetate extract by 45%, *n*-butanol extract by 43%, *n*-hexane extract by 45%, water extract by 59%, and hot-water stem extract by 32% (ZI) at 3000µg/disc. Furthermore, 2000µg/disc crude extract showed 57% ZI while ethyl acetate and *n*-hexane produced an equal zone of inhibition (45%). Similarly, *n*-butanol, water, and hot water exhibited equal ZI (32%) at 2000µg/disc. Crude extract showed 45% and *n*-hexane 48% ZI while ethyl acetate, *n*-butanol, hot water, and water

extracts produced equal zone inhibition of 32% at 1000µg/disc. Strong antibacterial potential against *A. tumifacians* was also noted in root extracts of *A. integrifolia* . Maximum inhibitory activity was found in crude methanol extract (77% ZI). The *n*-hexane reduced the growth of the same bacterium by 65%, ethyl acetate by 52%, *n*-butanol by 42%, and water roots extract by 40% ZI at 3000µg/disc. The crude methanol extract produced 65% and water root extract 38% ZI while *n*-hexane, ethyl acetate, and *n*-butanol revealed equal ZI (32%) at 2000µg/disc. Crude methanol extract exhibited 42% ZI while ethyl acetate and water extract showed equal ZI (32%). On the other hand, n-butanol and n-hexane revealed the same ZI of 16% at 1000µg/disc. Hot-water root extracts did not show efficacy at any concentrations.

The extracts of both stem and roots showed anti-bacterial efficacy against *X.oryzae* (Table 1&2). Crude methanol and *n*-hexane extracted fraction of stem produces an equal zone of inhibition of 63% while *n*-butanol produced 50% at 3000µg/disc. Furthermore, crude extract and *n*-hexane exhibited 63% and 53% ZI respectively while ethyl acetate and water roots extract revealed equal zone of inhibition (37.5%) at 2000µg/disc. Crude extract showed 50% and n-hexane 45 % ZI although, ethyl acetate and water roots extract produced similar ZI (38%) at 1000µg/disc. Hot-water root extract did not show efficacy at any concentration while *n*-butanol extract was inactive against *X.oryzae* at 1000 and 2000 µg/disc. On the other hand, the growth of *X.oryzae* was inhibited by crude methanol extracts of root (38% ZI), *n*-hexane (63% ZI), *n*-butanol(55% ZI), ethyl acetate (37.5% ZI) at 3000µg/disc. Similarly, crude extracted fraction revealed 38% ZI while *n*-hexane and *n*-butanol produced equal zone ZI (50%) at 2000µg/dis.

Table 1. Anti-bacterial potential of the stem extracts of Ajuga integrifolia against the different bacterial and fungal species

Bacterial /Fungi species	Extracts	% Zone of inhibition ±STDV		
		1000µg/disc	2000µg/disc	3000µg/disc
Bacillus subtilis	Methanol	54.4 ±1.1	54.5±1.4	54.6±1.1
	Ethyl acetate	32.7 ± 1.2	32.9± 1.6	49.2±1.3
	n-Hexane	32.5 ±1.3	32.6±1.2	32.6±1.2
	Butanol	40.8 ±1.4	49.1±1.3	49.2± 0.9
	Water	32.4± 1.1	49.2± 1.1	51.4±1.1
	Hot water	0	0	0
Agrobacterium tumefaciens	Methanol	42.4±1.3	58.4±1.2	59.5±1.3
	Ethyl acetate	30. 5 ±1.4	44.3± 1.0	44.5±1.6
	n-Hexane	44.8± 2.1	44. 5 ±1.1	44.7± 2.6
	Butanol	30.2±1.1	30.6± 1.1	40. 5 ±1.5
	Water	30. 5 ±1.2	30.8±1.3	59.3± 2.1
	Hot water	30.3±1.1	30.5± 2.1	30.6±1.6
Xanthomonos oryzae	Methanol	44.4±1.6	63.6± 1.1	63.8±1.6
	Ethyl acetate	39.5± 1.2	39.5±1.6	39. 5 ±1.5
	n-Hexane	42.4± 1.1	63.6± 1.6	63.8± 1.1
	Butanol	0	0	43.4±1.6
	Water	39. 5 ±1.5	39. 5 ±1.5	39.6± 1.1
	Hot water	0	0	0
Citrobacter freundii	Methanol	22.4±1.4	22.6± 1.4	63.2± 1.1
	Ethyl acetate	22.2± 1.2	22.6±1.7	38.2±1.3
	n-Hexane	24.8±1.1	50.3± 1.6	50. 5 ±1.4
	Butanol	24. 5 ±1.4	39.4±1.3	39.6± 1.1
	Water	22.4±1.6	22.6± 1.1	22.8±1.5
	Hot water	0	0	0
Alternaria alternata	Methanol	80.4± 1.1	82.6± 1.1	97.3± 1.1
	Ethyl acetate	74.2±1.5	76. 5 ±1.3	78.6± 1.2
	n-Hexane	76± 1.6	78.4± 1.4	80.6±1.3
	Butanol	60.2±1.7	80.6±1.6	83.4± 1.9
	Water	64.4±1.3	78.6± 1.1	83.6± 1.1
	Hot water	32.6±1.4	47.3± 1.1	50.4± 1.2
Alternaria solani	Methanol	66.4± 1.1	83.5± 1.1	97.2± 1.3
	Ethyl acetate	87.4±1.2	92.4±1.6	97.6± 1.1
	n-Hexane	80± 1.6	87.6± 1.1	97.8± 1.2
	Butanol	66.4±1.7	68.6±1.3	72.8± 1.1
	Water	86.6±1.5	90.4±1.2	97.6± 1.3
	Hot water	79.4± 1.1	83.8± 1.1	98.6± 1.2
Aspergillus niger	Methanol	71.3± 1.2	83.4± 2.1	98.4±1.4
	Ethyl acetate	67.2±1.3	78.5± 2.6	96.6±1.2
	n-Hexane	61.4±1.5	70.3±1.3	80.4±1.1
	Butanol	51.4±1.1	64.8±1.3	74.7±1.3
	Water	49.3± 1.1	60.6±1.6	70.8± 1.2
	Hot water	43.5± 1.2	49.6±1.3	73.4± 1.1

Table 2. Anti-bacterial potential of the root extracts of *Ajuga integrifolia* against the different bacterial and fungal species

Bacterial /Fungi species	Extracts	% Zone of inhibition ±STDV		
		1000µg/disc	2000µg/disc	3000µg/disc
Bacillus subtilis	Methanol	41.4±1.1	62.8±1.5	62.9±1.3
	Ethyl acetate	38.4±1.2	39.8± 2.1	39.9±1.3
	n-Hexane	16.2±1.4	48.8±1.3	51.4±1.5
	Butanol	62.9± 3	62.9±1.3	62.9± 2.1
	Water	48.6±2	48.6±1.5	51.4
	Hot water	0	0	0
Agrobacterium tumefaciens	Methanol	41.4±1.1	67.8±1.6	77.9± 1.1
	Ethyl acetate	31.4±1.2	31.6± 1.1	49.8±1.2
	n-Hexane	14.2±1.3	30.8±1.1	67.9±1.4
	Butanol	14.5± 1.1	30.9±1.4	38.8±1.1
	Water	30.5±1.1	39.5±1.3	41.2± 1.1
	Hot water	0	0	0
Xanthomonos oryzae	Methanol	39.5± 1.2	39.6±1.1	39.8±1.1
	Ethyl acetate	28.8±1.1	39.6±1.1	39.8±1.5
	n-Hexane	51.6±1.4	51.8± 2.1	63.5±1.4
	Butanol	19.6±1.1	51.6±1.1	53.5± 1.1
	Water	22.5±1.1	39.8±1.2	41.2±1.1
	Hot water	0	0	0
Citrobacter freundii	Methanol	43.6±1.2	43.7± 1.1	54.5±1.2
	Ethyl acetate	26.4±1.1	26.6±1.1	26.8±1.1
	n-Hexane	38.6± 1.3	38.8±1.6	48.5±1.3
	Butanol	38.6±1.2	38.8±1.1	38.9±1.4
	Water	0	38.6±1.3	38.8± 1.1
	Hot water	38.6±1.1	38.8±1.1	38.9±1.5
Alternaria alternata	Methanol	78.6±1.1	81.5±1.1	98.6±1.1
	Ethyl acetate	67.5± 1.1	70.4±1.1	98.4±1.1
	n-Hexane	86.8±1.2	90.5± 1.1	93.4±1.2
	Butanol	81.2±1.1	90.5±1.3	97.5±1.2
	Water	76.5±1.1	78.9±1.2	82.4± 2.1
	Hot water	43.2±1.1	63.8±1.1	68.8±1.1
Alternaria solani	Methanol	83.5± 2.1	90.4±1.3	98.5±1.5
	Ethyl acetate	83.6±1.3	91.5± 2.1	98.5±1.5
	n-Hexane	68.8±1.5	78.5±1.3	81.2± 2.1
	Butanol	0	0	0
	Water	68.9±1.3	71.4± 2.1	80.5±1.3
	Hot water	80.5±1.3	86.5±1.5	92.8± 2.1
Aspergillus niger	Methanol	49.8±1.3	68.5±1.1	90.4± 1.1
	Ethyl acetate	46.5±1.3	49.8± 1.1	84.5±1.2
	n-Hexane	49.6± 1.1	51.4±1.2	83.8±1.6
	Butanol	49.5±1.2	51.5±1.3	79.8± 1.1
	Water	37.5±1.1	49.8± 1.1	49.8±1.2
	Hot water	44.5± 1.2	49.8±1.3	49.8±1.1

Water and ethyl acetate produced similar ZI (38%) at the same concentration. Furthermore at 1000µg/disc *n*-hexane produced 50% and crude extract showed 38% ZI respectively while ethyl acetate, *n*-butanol and water stem extracted fractions revealed 30%, 20%, and 25% ZI respectively. Hot-water stem extracts revealed efficacy with 0% ZI at all concentration levels. The stem and root extracts of *A. integrifolia* also showed antimicrobial potential against *C. freundii.*

The crude extract of stem exhibited 63%, *n*-hexane 50%, and water extract 25% ZI while ethyl acetate and *n*-butanol produced equal ZI of 38% at 3000µg/disc. Furthermore, crude methanol, ethyl acetate, and water extract showed equal ZI of 25% while n-hexane exhibited 50% and *n*-butanol 38% ZI at 2000µg/disc. Further, the results of the study suggested that crude methanol, ethyl acetate, and water fraction exhibited equal ZI (25%) while *n*-butanol and *n*-hexane fraction produced similar ZI (28%) at 1000µg/disc. Hot-water fraction did not show ZI at any concentration.

The crude extracts of the roots and n-hexane produced 55% and 50% ZI respectively. Ethyl acetate, *n*-butanol, water, and hot-water roots revealed equal ZI (25%) at 3000µg/disc. The crude extract and *n*-hexane extract exhibited 43% and 38% ZI while water, hot water, *n*-butanol, and ethyl acetate roots showed equal ZI (25%) at 2000µg/disc. Furthermore, methanol and *n*-hexane fractions exhibited 43% and 38 % ZI while ethyl acetate, hot-water, and *n*-butanol roots fraction exhibited equal ZI (25%) at 1000µg/disc. The water roots extract sample was not active against *C. freundii* at 1000µg/disc.

Anti-Fungal Efficacy by Well Diffusion Method

The stem and root extracts of *A. integrifolia* were tested for anti-fungal efficacy. The strong antifungal potential was shown by crude methanol extract and formed 97%,

83%, and 80% zone of inhibition at 3000, 2000, and 1000µg /mL respectively. Ethyl acetate extracts revealed 77%, 73%, and 70% zone of inhibition at all three concentrations.

At 3000, 2000, and 1000µg/mL, *n*-hexane extract showed 83%, 77%, and 73% ZI while *n*-butanol extract formed 87%, 83%, and 61% ZI. Water and hot-water stem fractions indicated 83% and 50% ZI at 3000µg/mL while at 2000µg/mL showed 77% and 47% ZI respectively. Water and hot-water extract also revealed 67% and 33% ZI at 1000µg/mL. *A. integrifolia* root extracted fractions showed antifungal efficacy against *A. alternata*. The crude methanol extracts showed 97% 83% and 77%, ethyl acetate 97%, 73%, 67%, *n*-hexane 93%, 90%, 87%, *n*-butanol 97%, 93%, 83%, water fraction 83%, 77%, 73% and hot-water fraction 67% and 63% 43% zone of inhibition at 3000, 2000 and 1000µg/mL concentration.

Antifungal potential against *A. solani* was also shown by the stem and root extracts of *A. integrifolia* . Crude methanol, ethyl acetate, *n*-hexane, water, and hot-water stem extracted fractions revealed equal ZI (97%) while *n*-butanol produced 73% ZI at 3000µg/mL. The crude methanol extract reduced the growth of *A. solani* by 83%, ethyl acetate by 93% followed by *n*-hexane (87% ZI) *n*-butanol (70% ZI) at 2000µg/mL. Water fraction showed 90% ZI and hot water extract formed 83% zone of inhibition at 2000µg/mL. Furthermore, crude methanol, ethyl acetate, n-hexane, n-butanol, water, and hot-water extracted fractions revealed 67%, 87%, 80%, 67%, 83%, and 77% zone of inhibition respectively at 1000µg/mL concentration. Similarly, *A. integrifolia* root extracts were active against *A. solani.* Crude methanol and ethyl acetate extract exhibited equal ZI 97%, 93%, and 83% ZI at 3000, 2000, and 1000µg/mL. Although *n*-hexane extracts revealed 83%, 77%, 67%, water fraction 83%, 73%, 67%, and hot-water root extracts formed 93%, 87%, 83% ZI at 3000, 2000 and 1000µg/mL respectively. N-butanol root fraction did not reduce the growth of the same fungus at any concentrations. The findings of the study also revealed the anti-fungal efficacy of the stem and root of *A. integrifolia* against *A. niger.* Crude methanol and ethyl acetate extracts showed 97% and 93% ZI while *n*-hexane, *n*-buatanol, water, and hot-water extracted fractions revealed 80%, 77%, 70%, and 73% ZI respectively at 1000µg/mL. Crude methanol, ethyl acetate, *n*-hexane, *n*-butanol, water and hot-water stem fractions exhibited 83%, 77%, 73%, 67%, 63% and 50% ZI respectively at 2000µg/mL. Data also showed that crud methanol, ethyl acetate, *n*-hexane, *n*-butanol, water, and hot-water fractions exhibited 73%, 67%, 63%, 53%, 50%, and 43% ZI respectively at 1000µg/mL. Similarly, crude methanol extract of root exhibited strong anti-*A. niger* potential by forming 90% ZI followed by ethyl acetate and n-hexane extracts (83% ZI). Butanol extracted friction inhibited the growth of the same fungus by 80% 53%, 50% ZI at .2 and 1000µg/mL. Water and hot-water root extracts showed equal zone of inhibition (50%) at 3000 and 2000µg/mL while at 1000µg/mL water fraction showed 37% and hot-water extracts produced 43% ZI respectively.

Discussion

The current study evaluated the antimicrobial efficacy of *A. integrifolia* wall ex. benth extracts against pathogenic bacteria and fungi species. The extracted samples of the *A. integrifolia* were effective in antimicrobial efficacy. Antifungal efficacy of the *A. integrifolia* (stem and roots) is more effective as compared to antibacterial efficacy. Five solvents were used for the extraction from two different parts of the *A. integrifolia* (stem and roots) included: methanol, ethyl acetate, *n*-hexane, *n*-butanol water, and hot water. Methanol-extracted fractions revealed broad and maximum efficacy against both groups of microorganisms (bacteria and fungi) followed by *n*-hexane and ethyl acetate. The yield of the bioactive compound/amalgam extraction depends on the polarities of solvents, time, and temperature as well as the physical status and chemical composition of the sample (Dai and Mumper, 2010). Methanol roots and stem extracts revealed their effectiveness against all the selected bacterial strains. The activity of the same extracted fraction was also reported by Vohra and Kaur (2011) against *S. aureus.* Stem methanol extract was also effective against *B. subtilis, S. aureus K. pneumonia* and *E. coli* (Shakoor et al., 2014). Hexane root extract showed high efficacy against *X. oryzae*. Rahman et al. (2015) reported that *n*-hexane extracts of the stem revealed great efficacy against *B.subtilis and E. coli.* The result of the study indicated that hot-water stem and root extracts were found less effective against the bacteria species. The decrease in the effectiveness of hot-water extract may be due to partial denaturation of the bioactive compound present in extracts. The data stated that methanol roots and stem extract were active against selected fungi followed by ethyl acetate. The strong antifungal activities in the leaves of *A. bracteosa* : were also reported by Iftikhar et al. (2014) against *A. niger* and *A. fumigatu*s which further strengthen the findings of the current study. Furthermore, results also indicated that *n*-hexane, *n*-butanol, water, and hot water showed moderate activity against fungi species.

Solvent effects on the antimicrobial potential of extracts were also noted in the study. Among the tested samples, methanol was found best for the extraction of bioactive compounds followed by *n*-hexane. The same solvent was reported by Anwar et al. (2006) for the recovery of the highest amounts of bioactive compounds from the different plants. Similarly, Son et al. (2004) also reported methanol as the best solvent for the extraction of antioxidants compound from rice and other plants.

Conclusion

Stem and roots both parts were active against bacteria and fungi. Methanol was found best solvent for the extraction of bioactive compounds from different parts of the plants.

Declarations

Ethics Approval and Consent to Participate.
Not Applicable

Consent for Publication

Not applicable

Competing Interests

The authors stated that they have no competing interests.

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Growth Performance, Body Measurements and Live Weight Estimation of *Tülü* (Bactrian × Dromedary F1) Calves from Birth to Six Months of Age

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ABSTRACT

A hybrid camel *Tülü* (Bactrian male x Dromedary female F1) males are preferred in camel wrestling, which is a culture unique to Anatolia. In this study, changes of live weight (LW), daily weight gain (DWG), and body measurements (BMs) of *Tülü* calves in the first 6 months of age in a farm in Aydın province, Türkiye, were determined as well as developing equations to estimate LW from body measurements. *Tülü* calves average birth weight (BW) was 34.7±1.80 kg and reached 175.3±3.38 kg at the age of 6 months with a 0.768±0.03 kg DWG during this time. Although the monthly total weight gains and monthly DWG averages of the calves in the first 6 months were similar, the changes in monthly LW and BMs were statistically significant (P<0.01). Abdominal girth (AG) alone can be used to predict LW in the analysis performed to estimate LW from body measurements by stepwise regression (R^2=95.62%). In conclusion, *Tülü* calves had relatively high growth rate in their first six months of age, and unlike other livestock species, instead of hearth girth (HG), AG that includes the hump can be used to estimate LW of *Tülü* calves.

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Introduction

Bactrian and Dromedary camels have been reared in Anatolia, Türkiye for centuries, partially as pure breed, mostly as hybrids between the two species, notably for wrestling, an activity dating back to BC and nowadays, organized in 100 cities and towns in Western Anatolia, living both in rural areas and in large settlements (Çalışkan, 2016; Ertürk and Şanlı, 2018). After a dramatic decrease by 97% from 1960 to 2000 (Faye, 2020), the Turkish camel population has increased for the last twenty years, mainly due to the growing popularity of camel wrestling and more recently, to the emerging dairy production.

It is assumed that camel breeding in Türkiye is practiced more for the camel wrestling than for the products obtained from camels (meat, milk, leather, etc.) (Yılmaz et al., 2022). The increasing popularity of camel wrestling in Türkiye encourages more people to participate in wrestling. It has become a social activity in which men, women and children participate as a family. For this purpose, it was important to get strong animal with solid skeleton and imposing muscular mass. The heterosis effect occurring in hybridization between Bactrian and dromedary camels allows getting, "hybrids", better than the pure two species in terms of size, bone strength (thickness), muscle development, and adaptation to environmental conditions (Yarkın, 1965). The first generation (hybrid F1 Bactrian ♂ x dromedary ♀) is regarded as the most valuable animal for work and wrestling ability (Dioli, 2020). Although the term "hybrid" is commonly used, the two genitors of F1 belonging to the same genus *Camelus*, and the product of the crossing being fertile, the hybrid named *Tülü* in Turkish language, is a crossbreed rather than a true hybrid (Faye and Konuspayeva, 2012). Only male *Tülü* is used for wrestling where it is called "*Besrek*". Usually, F1 hybrid male camels were brought to Türkiye legally or illegally from Iran, Afghanistan and Syria (Koç et al., 2022). However, some Turkish camel breeders aimed to produce wrestling camels in their farms instead of bringing them from abroad.

Camel breeders want to know if hybrid F1 male calves will be a good wrestler in the future. Although each wrestling camel has its wrestling style (arm taking, tying, arm tying, fork tie, rubbing scruff, flapping, hook, overlay hook, etc.), some camel riders believe that the front legs should be long because it provides an advantage over their opponents during wrestling. Since it is allowed to wrestle camels from the age of 7 years (Manav et al., 2018), studies on whether a male *Tülü* will be a good wrestler while he is still in the calf stage can be put forward with a long-term research that will enable the participation of many camels.

Breeders also want to take advantage of some practical measurements to be recorded on the animal to know and estimate the live weight (LW) and growth of the animals if they are unable to weigh them. For this purpose, there are various LW estimation equations proposed in camels (Boué, 1949; Graber, 1966; Wilson, 1978; Field, 1979; Bucci et al., 1984; Abouheif et al., 1986; Yagil, 1994; Patel et al., 2007; Ihuthia, 2010; Koç et al., 2022). Kadim and Mahgoub (2013) stated that some body measurements (BM) such as shoulder height (SH), heart girth (HG) and abdominal girth (AG) are used to estimate the live weight of camels. Although equations for LW estimation in camels of different ages have been developed, Schwartz et al. (1983), Simpkin (1983), Bissa et al. (1998), Kamoun (2004), Kuria et al. (2007) and Ihuthia (2010) have developed LW estimation equations for young camels. In addition, without touching or disturbing the animal some morphological measurements of camels with three dimensional modelling method were also determined (Çağlı and Yılmaz, 2021), but a suggested formula to estimate LW for *Tülü*'s was not found among these studies.

The present stud aimed to determine the growth performances of *Tülü* calves up to 6 months of age, by weighing live weights and taking various BMs monthly. At the same time, correlation coefficients between LW, monthly weight gain (MWG), daily weight gain (DWG), and BMs were determined, and the equations for the estimation of LW from BMs were derived.

Material and Methods

This study was conducted on a camel farm in İncirliova/Aydın, Türkiye. Twenty-one *Tülü* calves, 14 of them male and 7 of them female, born from 2017 to 2021, were weighed and measured monthly until the 6th month of age between 10:00-12:00 before milking to determine LW, MWG, and DWG. The birth weight (BW) of calves and their BMs were taken within 24 hours after birth. A 2000 kg digital scale with 0.5 kg precision and a measuring meter and a 30 cm ruler were used for weighing and taking their BMs. BMs on calves were taken as described in Koç et al. (2022). The measurements taken are wither height (WH), rump height (RH), abdominal height (AH), body length (BL), hearth girth (HG), abdominal girth (AG), arm length (AL), neck length (NL), tail length (TL), rump width (RW) and shoulder width (SW).

The mothers of all calves were dromedary, sired with Bactrian bulls. In this camel farm, natural service was used, the Bactrian male being left in the group compartment with the non-pregnant camels, where he mates several times with the females showing heat. Mating season is prolonged from December to May.

Pregnant camels were kept in a pasture owned by the farmer between April and December, and when the weather got cooler, the animals were moved to the shelter and fed intensively. Pregnant camels, whose parturition approached, were moved to the individual birth pen, and after giving birth, they were housed with their calves in this pen until they reached approximately 2-3 months old. *Tülü* calves are accustomed to suckling their mothers after birth, so that they received colostrum and are fed accordingly.

Tülü calves were separated from their mothers at night after they were 2-3 months old, and they were kept apart until milking at 12:00-13:00 on the next day. With the start of milking time, the calf is provided to reach its mother to pre-stimulate her before milking. Then, the camel is milked by preventing the calf from suckling. Camels were milked with a mobile milking machine in the barn, but the residual milk was not collected and left to the calf. The calf, which remains with its mother for a while, is then separated and housed in a separate group compartment until milking the next day. The camel whose offspring died continued to be milked, so that it did not dry off, oxytocin being used for a week to stimulate milking.

Since their mothers will be used for milk production, when the calves reach the age of 2-3 months, calf starters produced for dairy cattle calves are given to them. They also consumed dry alfalfa grass that was constantly in front of them as roughage. The water requirements of the calves were met in the trough in front of them.

Statistical Analysis

The SAS (9.4) package program was used to analyze the data. The subgroups were compared according to Tukey test ($P<0.05$). Since the number of calves born in 2017, 2018, and 2019 was low, the data for these years have been combined. The statistical model used in the analysis of weight and BMs was as follows:

$$Y_{ijkl} = \mu + a_i + b_j + c_k + e_{ijkl}$$

Where

Y_{ijkl} : the observation value of the traits,
μ : the overall mean of the traits,
a_i : the effect of the year (I= ≤2019, 2020, 2021),
b_j : the effect of sex (j= male, female),
c_k : the effect of age as month (k= birth, 1, 2, 3, 4, 5 and 6 mo),
e_{ijkl} : the error term.

In addition, the correlation coefficients (Pearson correlation) between the traits were calculated and by using MINITAB 13.0 stepwise regression procedure, five equations to estimate LW from BMs were developed.

Results and Discussion

Birth weight (BW) did not vary significantly between years (Table 1). While the effect of age was found to be statistically significant ($P<0.01$) for all traits except MWG and DWG, the effect of sex was significant ($P<0.05$) only for NL and HG, while the effect of year was significant for LW ($P<0.05$), AH ($P<0.01$), NL ($P<0.01$), SW ($P<0.05$) and TL ($P<0.05$).

Tülü calves with a BW of 34.7±1.80 kg achieved an average of 23.38±0.87 kg per month and an average of 0.768±0.03 kg per day, reaching a weight of 114.5±3.18 kg at the age of third month and a weight of 175.3±3.38 kg at the age of sixth month (Table 1).

The first six-month, DWG average of those born in or before 2019 (0.831±0.06 kg) was found to be higher than those born in 2020 (0.748±0.04 kg) and 2021 (0.691±0.08 kg). In addition to the difference between the years, the fathers of the calves born in 2017-2018 on the farm was differed from those of calves born in 2019 and following years. Indeed, the Bactrian bull used for mating is generally changed every 5 years.

Table 1. Live weight (LW), monthly weight gain (MWG), daily weight gain (DWG), and body measurements of *Tülü* calves up to six months of age

Factor	n	LW	MWG	DWG	WH	RH	AH	AG
Year		*	NS	NS	NS	NS	**	NS
≤2019	23	114.0±1.77[a]	25.2±1.60	0.831±0.06	126.0±0.96	122.6±0.77	137.0±1.12[ab]	135.2±1.48
2020	32	108.8±1.54[b]	22.8±1.28	0.748±0.04	126.5±0.84	124.0±0.67	140.2±0.97[a]	139.1±1.29
2021	18	107.6±2.41[b]	20.3±2.25	0.691±0.08	124.9±1.32	123.0±1.05	134.9±1.53[b]	135.7±2.02
Sex		NS	NS	NS	NS	NS	NS	NS
Male	52	112.1±1.30	22.2±1.16	0.742±0.04	125.8±0.71	123.0±0.57	137.3±0.83	136.0±1.09
Female	21	108.2±1.95	23.3±1.76	0.771±0.06	125.8±1.06	123.3±0.85	137.5±1.24	137.3±1.64
Age, mo		**	NS	NS	**	**	**	**
Birth	21	34.7±1.80[a]	-	-	105.0±0.98[a]	102.5±0.78[a]	107.2±1.14[a]	78.9±1.51[a]
1	16	60.6±2.05[b]	24.4±1.56	0.788±0.05	114.8±1.12[b]	112.7±0.90[b]	123.3±1.30[b]	107.9±1.72[b]
2	11	88.7±2.48[c]	27.7±1.95	0.893±0.07	122.8±1.35[c]	120.8±1.08[c]	132.9±1.57[c]	126.9±2.08[c]
3	7	114.5±3.18[d]	21.7±2.44	0.738±0.08	128.7±1.73[cd]	126.1±1.09[d]	142.1±2.02[d]	142.7±2.66[d]
4	6	139.1±3.38[e]	24.3±2.58	0.796±0.09	131.8±1.84[de]	128.7±1.48[de]	147.1±2.14[de]	158.1±2.84[e]
5	6	158.0±3.38[f]	18.3±2.58	0.641±0.09	137.1±1.84[ef]	133.4±1.48[ef]	152.3±2.14[ef]	166.3±2.84[ef]
6	6	175.3±3.38[g]	20.3±2.58	0.686±0.09	140.5±1.84[f]	138.0±1.48[f]	156.8±2.14[f]	175.9±2.84[f]
Overall	73		23.38±0.87	0.768±0.03	119.99±1.55	117.42±1.49	129.49±2.22	120.36±4.10

Factor	n	BL	NL	HG	SW	AL	RW	TL
Year		NS	**	NS	*	NS	NS	*
≤2019	23	88.1±1.12	54.1±1.02[a]	118.1±1.18	17.6±0.57[a]	101.2±1.20	14.1±0.34	42.9±0.66[ab]
2020	32	87.4±0.97	55.4±0.89[a]	120.1±1.03	19.5±0.50[b]	104.2±1.04	14.1±0.30	42.9±0.58[a]
2021	18	85.7±1.52	59.9±1.39[b]	118.0±1.61	19.2±0.78[ab]	103.6±1.64	13.8±0.46	45.2±0.90[b]
Sex		NS	*	*	NS	NS	NS	NS
Male	52	87.7±0.82	57.7±0.75[a]	120.3±0.87[a]	19.0±0.42	102.8±0.88	13.7±0.25	43.5±0.49
Female	21	86.5±1.23	55.2±1.13[b]	117.2±1.30[b]	18.5±0.63	103.2±1.33	13.7±0.38	43.8±0.73
Age, m		**	**	**	**	**	**	**
Birth	21	60.6±1.13[a]	41.9±1.03[a]	80.6±1.20[a]	13.4±0.58[a]	88.0±1.22[a]	9.8±0.35[a]	32.7±0.67[a]
1	16	74.3±1.30[b]	47.4±1.18[b]	100.8±1.37[b]	16.5±0.67[b]	97.0±1.39[b]	12.3±0.40[b]	38.0±0.78[b]
2	11	88.7±1.57[c]	50.3±1.43[b]	113.8±1.66[c]	19.0±0.81[bc]	99.9±1.69[bc]	14.1±0.48[bc]	40.4±0.93[bc]
3	7	88.9±2.01[cd]	60.5±1.83[c]	124.9±2.12[d]	19.4±1.03[bc]	105.3±2.16[cd]	13.7±0.61[bc]	44.7±1.19[cd]
4	6	96.4±2.14[de]	61.8±1.95[c]	132.4±2.26[de]	19.8±1.10[bc]	106.9±2.30[cd]	13.8±0.65[bc]	48.5±1.27[de]
5	6	102.6±2.14[e]	65.6±1.95[c]	137.8±2.26[e]	21.2±1.10[c]	111.7±2.30[d]	14.9±0.65[cd]	49.5±1.27[e]
6	6	104.2±2.14[e]	67.8±1.95[c]	140.9±2.26[e]	22.0±1.10[c]	112.2±2.30[d]	17.1±0.65[d]	51.8±1.27[e]
Overall	73	80.01±1.92	52.03±1.16	109.10±2.67	17.55±0.47	98.93±1.19	12.63±0.30	40.15±0.81

WH: wither height, RH: rump height, AH: abdominal height, AG: abdominal girth, BL: Body length, NL: neck length, HG: hearth girth, SW: shoulder width, AL: arm length, RW: rump width, TL: tail length, LW: live weight, MWG: monthly weight gain, DWG: daily weight gain.

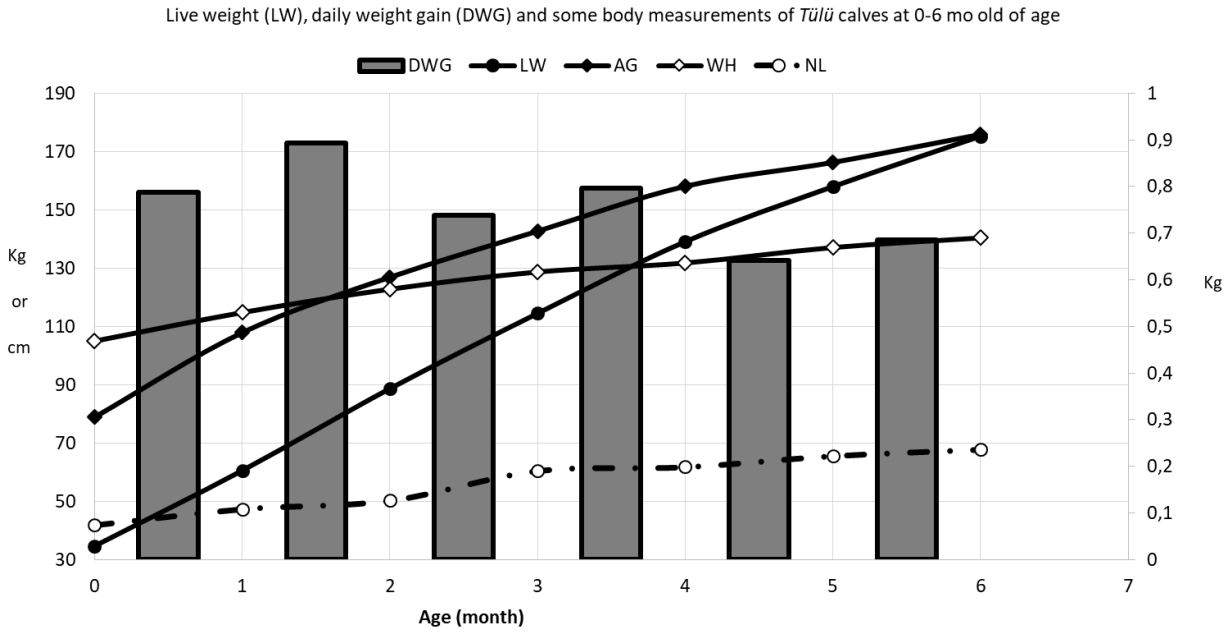

Figure 1. Changes of live weight (LW), daily weight gain (DWG), wither height (WH), abdominal girth (AG) and neck length (NL) in Tülü calves from birth to 6 months of age.

The monthly changes of LW, DWG, WH, AG, and NL in *Tülü* calves from birth to 6 months of age, reported in Figure 1, show that although DWG was high in the first two months, a fluctuating course occurred in the later months, then a decrease was observed due to the restriction of milk feeding, the calves being used only for stimulating their mothers for milking by their presence. Although the differences between the months were statistically not significant, DWG, which was 788 g in the first month, increased to 893 g in the second month, then decreased below 800 g in the third and fourth months, and below 700 g in the fifth and sixth months (Figure 1).

Unlike other farm animals, apart from hump, camels also have a long neck. Their NL, which was 41.9±1.03 cm at birth, reached 67.8±1.95 cm at the age of six months. On the other hand, front leg lengths increased from 88.0±1.22 cm at birth to 112.2±2.30 cm in the 6th month of age.

Weights at Different Age

Birth weight (BW): Season (i.e. photoperiod), which has a significant effect on reproductive traits, also affects fetal development in camels (Nagy and Juhasz, 2019). These researchers stated that the mother camel is the factor with the greatest influence on birth weight, followed by parity, year, and month of birth, but the share of mother breed, gender, sire, gestation length and maternal age is lower. Kadim and Mahgoub (2013), suggested that the heritability of BW in camels was higher than in other meat species, and that high BW, which is affected by the sum of the factors contributing to the nutrition of the fetus in the uterus, results in higher calf viability and higher growth rate.

In the present study, BW obtained for *Tülü* calves (34.7±1.80 kg) was determined to be higher than the values reported for dromedary calves in some previous studies (Harmas et al., 1990; Hammadi et al., 2001; Bakheit et al., 2009). The BW mean obtained in our study was close to the means reported for dromedary calves in UAE: Nagy and Juhasz (2019) reported 34.5±0.09 kg, and Bene et al. (2020) reported 34.75 ± 5.67 kg. Koç et al. (2022) stated that the birth weight of F1 *Tülü* calves ranged from 26 kg to 51 kg and calculated the BW in *Tülü* calves in Türkiye as 35.99±1.25 kg on average, slightly higher than the average BW obtained in the present study. Nagy and Juhasz (2019), stated that the birth weight of dromedary camel ranged between 10 and 64 kg from 3909 data belonging to 6 different genotypes from the records kept for 10 years in a farm in Dubai.

The average BW in Indian camels was 39 kg (Bissa, 1996) and Sabahat et al. (2021) stated that BW in dromedary camels showed significant variation according to the regions, breed and within breed, and reported an average of 35 kg. According to Hammadi et al. (2001) BW in camels was affected by the level of feeding and reported that females receiving supplement feeding in Tunisian dromedary camels had 8 kg higher BW in their calves (31±4 kg) than those having no supplement (23±2 kg).

The BW average obtained for *Tülü* calves in the present study was lower than the average reported by Dioli (2020) for hybrid F1 camels (45.4 kg) which was higher than the average for dromedary and Bactrian calves. He also stated that hybrid F1 camels had higher growth rates. Fatih et al. (2021) reported BW of eight different Pakistani camel breeds (Bravhi, Kachi, Kharani, Kohi, Lassi, Makrani, Pishin and Rodbari) ranged from 37.24 kg to 47.29 kg in females and 40.08 to 50.27 kg in males. These authors determined that BW means of these breeds were higher than the average obtained for *Tülü* calves in the present study.

The average BW observed here was also lower than the mean reported by Sahani et al. (1998) for Indian (indigenous) and semi-intensive reared Bikaneri (38.20±0.47 kg), Jaisalmeri (36.46±0.61 kg) and Kachchhi (35.13±0.64 kg) breeds. In a study of Bactrian camels in China, Zhao et al. (2000) reported slightly lower BW (34.55±7.17 kg) than the value found for *Tülü*s in our present study.

Three-month LW (114.5±3.18 kg) and six-month LW (175.3±3.38 kg) averages of *Tülü* calves determined in the present study were higher than the averages reported by Sahani et al. (1998) for Indian Bikaneri (89.095±1.57 kg and 150.27±1.45 kg), Jaisalmeri (87.172±1.81 kg and 146.22±1.69) and Kachchhi (89.085±2.92 kg and 144.43±1.63 kg) breeds at the same age. It was also higher than Chinese Bactrian camels reported by Zhao et al. (2000): three- and six-month LW in Bactrian camels were 91.83±10.48 kg and 140.6±19.63 kg, respectively.

The mean LW obtained for three-month-old *Tülü* calves observed in our study was also higher than Tunisian dromedary calves reported by Hammadi et al. (2001) who found 79 kg. However, it was slightly lower than Indian dromedary calves (119 kg) at the same age according to Bissa et al. (1998). Besides, the average 6-months LW in our study was slightly higher than the value (171 kg) reported by the same author.

In traditional camel farming systems worldwide calves suckle their mothers after birth, and weaning usually occurred between 3 months and 12 months (Faye et al., 2021) or even more. In our monitored farm, the weaning age reached over12 months and the lactating camels were milked depending on the demand for milk. Thus, the milking was not complete. Important residual milk was left to the calf. The milk yield of the mother is consequently underestimated, and the amount of residual milk suckled by the camel calf could significantly effect on its growth performance. Thus, if globally, the birth weight of *Tülü* camel calf was not exceptional, the growth appeared interesting at least until 6 months of age. The results regarding daily weight gain confirm this.

Daily Weight Gain

As with other livestock species, the nutritional status or dietary energy and protein content of camels have a significant impact on their growth performance. In camels, the growth curve is sigmoidal (Kadim and Mahgoub, 2013) and they have an inflection point at the age of 7-8 years (Kadim et al., 2008).

DWG mean found in this study was 0.768±0.03 kg and varied between 0.641±0.09 kg and 0.893±0.07 for *Tülü* calves in the first six months and these values were detected to be higher than the overall means of Bikaneri, Jaisalmeri, and Kachchhi camels in India reported by Sahani et al. (1998): 0.605 ± 186 kg/day from birth to 3 mo of age and, 0.627 ± 0.014 kg from 3 to 6 mo of age. Such difference could be due to the heterosis effect mentioned above and to the more intensive feeding conditions.

Table 2. Correlation coefficients between live weight, monthly weight gain, daily weight gain, and body measurements of *Tülü* calves from birth to six months of age

	RH	AH	AG	BL	NL	HG
WH	0.973**	0.972**	0.947**	0.910**	0.853**	0.937**
RH		0.972**	0.957**	0.916**	0.839**	0.942**
AH			0.972**	0.924**	0.832**	0.959**
AG				0.951**	0.852**	0.977**
BL					0.807**	0.929**
NL						0.867*
HG						
SW						
AL						
RW						
TL						
LW						
MWG						

	SW	AL	RW	TL	LW	MWG	DWG
WH	0.765**	0.900**	0.774**	0.873**	0.949**	-0.075	-0.044
RH	0.759**	0.900**	0.775**	0.867**	0.948**	-0.160	-0.124
AH	0.781**	0.900**	0.768**	0.889**	0.955**	-0.128	-0.100
AG	0.753**	0.860**	0.744**	0.915**	0.976**	-0.099	-0.063
BL	0.695**	0.804**	0.689**	0.883**	0.942**	-0.141	-0.107
NL	0.630**	0.818**	0.695**	0.875**	0.862**	-0.236	-0.121
HG	0.775**	0.840**	0.737**	0.905**	0.959**	-0.167	-0.111
SW		0.772**	0.577**	0.638**	0.717**	-0.101	-0.062
AL			0.736**	0.815**	0.838**	-0.134	-0.120
RW				0.718**	0.757**	-0.046	-0.019
TL					0.911**	-0.169	-0.105
LW						-0.121	-0.072
MWG							0.938**

WH: wither height, RH: rump height, AH: abdominal height, AG: abdominal girth, BL: Body length, NL: neck length, HG: hearth girth, SW: shoulder width, AL: arm length, RW: rump width, TL: tail length, LW: live weight, MWG: monthly weight gain, DWG: daily weight gain

Table 3. Equations developed by using body measurements for predicting live weight of *Tülü* calves up to six months of age

	Equations	R^2	Std. Deviation
1	LW = -76.59 + 1.36 AG	95.31	10.6
2	LW = -145.28 + 1.04 AG + 0.89 WH	95.91	10.0
3	LW= -133.89 + 1.05 AG + 1.28 WH -0.59 AL	96.20	9.73
4	LW = -130.17 + 1.00 AG + 1.19 WH - 0.72 AL + 0.50 NL	96.45	9.47
5	LW= -134.76 + 1.02 AG + 1.27 WH -0.66 AL +0.45 NL- 0.70 SW	96.58	9.36

LW: live weight, AG: abdominal girth, WH: wither height, AL: arm length, NL: neck length, SW: shoulder width.

DWG average in our study for the first six months was higher also than the results (between 0.500 and 0.605 kg/day) reported by Field (1979), Wilson (1992), Hammadi et al. (2001), Musavaya (2003), Ihuthia (2010), but comparable (0.733-0.760 kg) to the observations of Kamoun (1993), Bissa (1996), El-Badawi (1996), Khanna et al. (2004) and Iqbal et al. (2001) in dromedary calves. It was also higher than Chinese Bactrian calves (Zhao et al., 2000). For example, the 6-month DWG was 0.500 kg/day only for Zarrin et al. (2020).

Similar to DWG obtained in *Tülü* calves in the first months of the present study, Hammadi et al. (2001) found an average DWG of 0.806 kg/day in camel calves issued from females supplemented from parturition to 90 days' post-partum, *vs* 0.376 kg only in non-supplemented.

In another study, Khanna et al. (2004) reported that DWG of Indian Jaisalmeri and Bikaneri breeds between 0-3 months of age was 0.700 and 0.770 kg, respectively, which was close to DWG of *Tülü* calves in the first and third months and but lower than the mean observed in the second month in our study. Musavaya (2003) determined that DWG in Kenya dromedary calves was 0.411 kg and 0.380 kg in males and females, respectively, much lower than our results. Under appropriate feeding conditions in Kenya dromedary calves, Wilson (1992) reported 0.870 kg DWG in the first month that is higher than the value (0.795±0.052 kg) obtained in our study for the same time, but in the same investigation, DWG up to 6 months was 0.570 kg only that was lower than our results. In Egyptian dromedary camels, El-Badawi (1996) reported higher weight gain from birth to six months of age, except for the weight gain found in the second month of our study, as 0.830-0.970 kg per day.

Although six-months DWG mean obtained in this study was similar to the mean obtained by Iqbal et al. (2001) in Pakistani dromedary camels in the same period, our second-month value (0.893 kg) was higher, but our values for the 4, 5 and 6 months were lower than their values for the same months.

Considerably lower values were reported in Kenyan pastoral system (Ihuthia, 2010) with 8-month DWG of 0.212 kg. Such low performance was attributed to the low milk availability of the mother in relationship with the abundance and quality of pastoral resources. Thus, Field (1979) reported that DWG was 0.222 kg and 0.655 kg during the dry and rainy years, respectively.

Hammadi et al. (2001) stated that small amount of milk is sufficient to provide moderate growth in calves due to the low requirements for nutrients in the first month and added that the milk yield of the mother will have a significant effect on the growth rate in the following months. Kamoun (2004) stated that DWG of camel calves from birth to one-year-old age could reach 1000 g under appropriate management and feeding conditions.

DWG of calves was higher in the period when the mother's milk yield was high, but DWG could be negative in the period when the milk yield decreased (Zhao et al., 2000). For Chinese Bactrian calves, DWG in the third (0.782±0.349 kg) and fifth (0.667±0.17 kg) months was reported by Zhao et al. (2000) to be slightly higher than the averages obtained for *Tülü* calves at the same months in this study, but lower than DWG obtained in the other months.

Correlations

Correlations between LW of *Tülü* calves and BMs were all positive and highly significant (r=0.717-0.976; P<0.01), while there were no significant relationships between LW and MWG and between LW and DWG (Table 2). There were no significant correlations between DWG and MWG with BMs. Correlations between BMs were obviously all positive and highly significant, too.

Unlike this study where the highest correlation was between LW and AG (r=0.976; P<0.05), Koç et al. (2022) calculated the highest correlation between BW and HG (r= 0.782 P<0.05) in *Tülü* calves.

At birth, HG and AG measurements were very close to each other in *Tülü* calves (Table 1). A similar finding was also observed in Koç et al. (2022). In their study on *Tülü* calves, HG was only 0.64 cm longer than AG, while in this study HG was also 1.7 cm longer than AG. When the *Tülü* calves reached the age of 6 months, the AG had a length of 35 cm longer than the HG. It is clear that a large part of this difference is due to the growth of the hump and its filling with fat.

On the other hand, compared to the values at birth, at 6 months of age, as LW increased 5.05 times, AG, HG, RW, BL, SW and NL increased 2.23, 1.75, 1.75, 1.72, 1.64 and 1.62 times, respectively. This shows that the development of tissues and internal organs of *Tülü* calves is different after birth and their share in LW is not the same as at birth.

Live Weight Estimation

Breeders want to know the animals' developmental status and weights at different ages. Knowing LW plays an important role in determining the price of the animal at selling or buying. However, there is no scale for weighing animals in field conditions and in every farms. For this purpose, estimating LW from BMs with various equations is possible.

Five equations developed by stepwise regression to estimate LW of *Tülü* calves from BMs were proposed (Table 3). In the first one, LW was estimated by using AG (R^2=95.31, Std. Dev.=10.6). If WH, AL, NL and SW are used in addition to AG to estimate LW, R^2=96.58 and Std. Dev.=9.36.

Unlike the equation derived in this study, Kuria et al. (2007) stated that HG gave the best estimate in suckling calves. Like this study, Ihuthia (2010) stated that the best single estimator of LW was AG. In a recent comparative study on the accuracy of published equations for estimating LW from BMs in camels, Field (1979) proposed LW estimation equation was reported to be the best option (Boujenane, 2019). Field (1979) proposed an equation estimating LW from WH, HG and AG measurements.

Although Koç et al. (2022) suggested the use of HG alone to predict BW (R^2=61.16) in *Tülü* calves, in this study it was found that HG would be insufficient to predict LW in the following months, and using AG, including hump, would be a more accurate predictor of LW (R^2=95.31).

The equations obtained in our study are valid for *Tülü* calves with a LW ranging between 26 kg and 195.5 kg, and it should be emphasized that the error will be much higher in the estimations to be made using these equations for weights other than these values. Such a situation was described by Devore and Pack (1993) as “danger of extrapolation”.

Conclusion

As well as camels’ wrestling abilities, their body structure also provides important advantages to apply their wrestling style during wrestling and to gain superiority over their opponents. Considering that a wrestling camel starts wrestling at the age of 7 years, deciding whether the animal is a good wrestler by looking at BMs and body weight after birth requires a long-term study involving many animals. By paying attention to the developments and changes in LW and BMs of *Tülü’*s at birth and after, it may be possible to make some inferences about which wrestling styles the wrestling camels can do better in the future. Starting from this point, under intensive conditions, DWG of *Tülü* calves in the first six months of their life has been varied between 641-893 g. Using only AG in estimation of body weight in *Tülü* calves, which considers the hump, and which shows significant improvement after birth and has a significant share in body weight, will increase the accuracy of LW estimation.

Declarations

Conflict of Interest

The authors declare that they have no conflict of interest.

Authors’ Contributions

Atakan Koç: Concept and design of the study, data collection and analysis and writing of the manuscript.

Alkan Çağlı: data collection. All authors read and approved the final manuscript.

Ethical Approval

With the decision of Aydın Adnan Menderes University Animal Experiments Local Ethics Committee (Aydın ADU-HADYEK) numbered 64583101/2022/101, it was stated that "there is no ethical objection to conducting the research".

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Data Availability

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Consent for Publication

Not applicable.

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The Weeds in Sunflower Crops when Grown in Arid Conditions of The Steppe of Ukraine

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ABSTRACT

In the arid conditions of the Steppe of Ukraine, the species composition of weeds characteristic of this soil-climatic zone develops. The correctly chosen method of basic soil tillage determines the effectiveness of weed suppression while simultaneously improving the growing conditions for sunflower varieties and hybrids. The purpose of the study was to identify the species composition of weeds in the steppe zone and establish the effectiveness the methods of basic tillage of soil in the technology of growing sunflower hybrids aimed at suppressing weeds and reducing the quantity of weeds in agrocenoses. Research has established that weeds of sunflower agrophytocenoses are represented by 78 species that belong to 2 classes, 18 orders, 27 families, 62 genera. In the agrophytocenosis of sunflower, the largest number of 93.5-96.3% is represented by dicotyledonous weeds (Magnoliopsida). The species composition is dominated by weeds of the Compositae family (Asteraceae) of the dicotyledonous class (Magnoliopsida), which leads to a significant decrease in the yield level. According to the species composition, 3 groups of weeds of the Asteraceae family (Asteraceae) were identified, of which 1 group of weeds is the most harmful and leads to the formation of a minimum yield of sunflower hybrids Yason and Daryi of 1.77-1.79 t/ha. The use of non-moldboard tillage leads to a percentage increase in the share of air dry mass of weeds of the *Asteraceae* family by 11.1-13.1%, while reducing the yield of sunflower hybrids by 0.13-0.21 t/ha. Thus, with the established species composition of weeds and the quantity of weeds, the use of plowing in sunflower cultivation technology makes it possible to form a maximum yield of 2.07-2.24 t/ha, providing more effective weed suppression in sunflower agrophytocenoses with a minimum percentage of air-dry mass of weeds of the Asteraceae family to the total number of weeds of 21.1-24.1%.

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Introduction

Of all oilseeds grown in Ukraine, sunflower is the most common crop. Over 90.0% of oils in Ukraine are made from sunflower seeds. Sown areas of sunflower in Ukraine are about 6.0 million hectares, which is approximately equal to 23.0% of the total sunflower area in the world. The soil and climatic conditions of the Steppe, southern and central parts of the Forest-Steppe are quite consistent with the biological properties of sunflower. A decrease in the assortment of crops grown in crop rotation has led in these parts of Ukraine to the greatest saturation of sunflower crop rotation (Adamenko, 2005; Aksyonov, 2003; Pakhnits & Dranishchev, 2001).

Sunflower cultivation provides the greatest economic efficiency of the functioning of agricultural enterprises in Ukraine, due to its high profitability, demand for marketable seeds and sunflower oil both in the country and outside the country.

With an average world sunflower yield of 1.75 t ha^{-1}, the average yield of this crop in Ukraine in recent years has reached 2.0 t ha^{-1}. The increase in yield is due to the cultivation of new sunflower hybrids with a higher level of genetic productivity potential (Gavrilyuk and Aksyonov, 2013).

However, a further increase in yield, a wider disclosure by the hybrids of their genetic potential for productivity is hindered by a low level of agricultural production technologies, a high level of weediness in crops (Bazdyrev et. al., 2004; Zakharenko, 1996).

High level weediness of crops and a high number of weed seeds in the arable soil layer create high competition in sunflower plants in agrocenoses, lead to significant unproductive losses of soil moisture and nutrients, shading and oppression of sunflower. These factors are one of the main reasons for the decline in yields of varieties and hybrids (Kott, 1964; Tatariko et.al., 2001).

It is known that sunflower, especially at the beginning of growth, is weakly resistant to weeds due to its biological characteristics. Even a small number of weeds in the rows reduces the yield. Agricultural techniques (pre-emergence and post-emergence harrowing, inter-row tillage) do not always ensure complete weed control (Zakharenko, 1996).

This is especially noticeable in our time, when there is an increase in crop litter and there is a species reorganization of the agrocenoses by weeding. Especially significant decrease in sunflower yield is observed with an increase in weediness of crops in fields with a low level of crop cultivation (Grigora, 2000; Kosolap, 2004).

As a result of the complex negative effect of weeds on plants, the level of productivity decline can reach from 40.0 to 80.0% (Pakhnits & Dranishchev, 2014).

The development and introduction into production of agricultural methods for weed control in Ukraine does not yet provide sufficiently effective methods for weed control in sunflower agrocenoses.

Insufficient knowledge of the species spectrum of weeds in agrophytocenoses significantly reduces the effectiveness of weed control during the growing season of sunflower.

The effectiveness of the developed methods is limited by the absence and discrepancy in the interpretation of the obtained data regarding biology and the growth of the most common and harmful weeds in agrocenoses in the south-eastern part of the northern Steppe of Ukraine.

Therefore, it becomes relevant to study and establish the species composition of weeds in sunflower crops, which will increase the efficiency of the development and use of agricultural methods aimed at the maximum weed control, increase the competition of sunflower with respect to weeds.

The aim of the research:

- to establish the weediness of crop rotation fields against the background of plowing and non-moldboard tillage of the soil when growing sunflower hybrids in the Steppe of Ukraine;
- to determine the effect of the method of base soil tillage on changing the type and level of weediness of fields;
- to establish the effect of the methods of base soil tillage and the level of weediness on the yield of sunflower hybrids formation;
- to determine the reaction of sunflower hybrids to the use of methods of base soil tillage and changes in the type and level of weediness.

Materials and Methods

The research was carried out in the farm "Adonis" of the Belovodsky district of the Luhansk region of Ukraine during 2014-2021.

The soil of the experimental site is represented by typical chernozem on loess-like loams with a humus layer thickness of 50 cm. The humus content in the arable soil layer according to Tyurin is 3.0-3.5%. The smallest moisture content of a meter layer of soil is 22-25%.

The experiments were carried out in a five-field crop rotation: fallow - winter wheat - corn grown for grain - spring barley - sunflower.

In the experiment to study the influence of the main tillage methods on the yield of sunflower hybrids and the number of weeds in the agrocenosis, the depth of the main tillage was 20–22 cm. Plowing was carried out with a PN-4-35 plow. Non-moldboard tillage was carried out with an anti-erosion agricultural cultivator KPG-250. The basic tillage practices (ploughing and moldboard-free ttillage of soil) were carried out in the first decade of October. The technology for growing hybrids of sunflower was generally accepted for the conditions of the Steppe of Ukraine. In spring, pre-sowing tillage consisted of early spring harrowing and one pre-sowing cultivation with simultaneous application of soil herbicide Harnes at a dose of 2.0 litres/ha. The depth of pre-sowing cultivation is 6-8 cm. The sowing depth of sunflower hybrids seeds is 6-8 cm. The term of sowing of sunflower hybrids is third decade of April.

The sunflower hybrids were sown at row spacing width of 70 cm. Plant stand density before harvesting is 50 thousand plants per hectare.

The care of sunflower crops included:

- harrowing after the emergence of sunflower sprouts;
- two inter-row cultivations of sunflower crops.

The species composition of weeds was established in a crop rotation with sunflower cultivation and in experiments to study the weediness of sunflower crops.

Inspection of the species composition of segetal weeds and pathways of weediness of sunflower crops was carried out using the route-expeditionary method. The abundance of weeds in agrocenoses was determined by a quantitative method.

The quantitative method for determining the weediness of crops was based on counting the number of weeds on the counting plots. When calculating, special frames with a size of 50 cm × 50 cm were used. The frames were superimposed in such a way that one of the crop sowing rows was its diagonal. After calculating the number of weeds within the framework, their average number was determined per one frame and with subsequent recalculation per 1 square meter. The degree of weediness of crops was determined on a scale (Table. 1).

Table 1. Scale for determining the degree of weed infestation

Weed quantity per 1 m^2	Weediness point	Weediness degree
1-5	1	very slight
6-15	2	slight
16-50	3	average
51-100	4	severe
more 100	5	very severe

Inspection of sunflower agrophytocenoses and counting the quantity of weeds was carried out at the beginning of the growing season (in spring), in summer in July; and at the end of the growing season (autumn).

The area of the sowing plot is 240 m^2, the registration area is 210 m^2. Experimental plots were placed in a randomized fashion in 4-fold repetition.

The experiment was set up with four replications according to the Randomized Blocks Trial Design, the statistical analysis of the obtained data was made in the according to the methods and statistical program (Aksyonov et. al., 2023; Dospekhov, 1985) and the Least Significant Difference (LSD) values.

Results

Observations to determine the composition of weeds in crop rotation fields showed that the species composition of weeds in agrophytocenoses was determined not only by natural conditions and the nature of anthropogenic impact, but also by the biological properties of crops used in crop rotation technologies.

During the research period, 78 types of weeds were found in crop rotations of the farm, which were assigned to 2 classes, 18 orders, 27 families, 62 genera (Table 2).

The class of Dicotyledonous (*Magnoliopsida*) weeds predominated in sunflower crops from growing weeds. The proportion of dicotyledonous weeds was 93.5-96.3%. The class of Monocotyledonous (*Liliopsida*) weeds accounted for 6.5-3.7%.

The weeds class of Dicotyledonous (*Magnoliopsida*), which grew in sunflower agrophytocenoses, included 26 botanical families of segetal species. Only one family belonged to the Monocotyledonous (*Liliopsida*) weed class.

The most quantity weed families by species composition included: Astereae (*Asteraceae*), Cabbage (*Brassicaceae*) (Table 3).

The families of weeds Astereae (*Asteraceae*) and Cabbage (*Brassicaceae*) in sunflower crops were represented by 18 and 9 species, respectively.

The families Labiate (*Lamiaceae*), Borage (Boraginaceae), Legume (*Fabaceae*) accounted for significantly fewer weed kinds. The family Labiate (*Lamiaceae*) had 6 species of weeds in sunflower crops, the family Borage (*Boraginaceae*), Legume (*Fabaceae*) – 4 species.

The less quantity of weed species – two each, accounted for the families Chenopodiaceae (*Chenopodiaceae*) and Euphorbiaceae (*Euphorbiaceae*).

The weeds of the Astereae family, having the highest percentage in the infestation of sunflower agrophytocenoses, were subdivided into three groups according to their species composition. Groups of weeds according to the species composition of weeds of this family were determined by the type of weediness in the crop rotation fields.

The first group of weeds growing in sunflower agrophytocenoses included: small-flowered quick weed (*Galinsoga parviflora Cav.),* common groundsel *(Senecio vulgaris L.)*, acantholeaf thistle (*Carduus acanthoides L.*), common thistle (*Cirsium vulgare (Savi) Ten*), bristly thistle (*Cirsium setosum (Willd) Bess),* creeping thistle (*Cirsium arvense (L) Scop.*).

The second group of weeds included: common chicory (*Cichorium intybus L.*), medicinal dandelion (*Taraxacum officinale Webb. Ex Wigg.*), yellow thistle (*Sonchus arvensis L.*).

The third group of weeds of the Astereae (*Asteraceae)* family, having a different species composition in sunflower agrophytocenoses, included: tartar lettuce *(Lactuca tatarica (L) C.A. Mey*), yellow thistle (*Sonchus arvensis L.*), ragweed (*Ambrosia artemisifolia L.*).

The first group of weeds of the family of Astereae (*Asteraceae)* had the most harmful effect on the yield of sunflower. With the same level of weed quantity of 1.7 pieces per 1 square meter, sunflower hybrids Dariy and Yason formed a minimum yield level of 1.77-1.79 t/ha in agrophytocenoses with the species composition of weeds of the first group (Figure 1).

In agrophytocenoses with the species composition of weeds of the second and third groups, a higher competitiveness of sunflower in relation to weeds was observed. In these agrophytocenoses, the hybrids formed the yield at the level of 1.87-1.90 t/ha.

In the agrophytocenoses of sunflower grown for plowing, the percentage of weeds of the Astereae (*Asteraceae)* family was 18.5-20.0% in relation to the total number of weeds of other families. Sunflower hybrids with such a number of weeds of this family for plowing formed a yield within 2.07-2.24 t/ha.

The use of moldboard-free tillage in the technology of sunflower cultivation led to an increase in the number of weeds of the family of Astereae (*Asteraceae)* by 10.0-12.0%, while reducing the yield of sunflower by 0.21-0.23 t/ha compared to the cultivation of sunflower by plowing (Table 4).

Table 2. Taxonomic composition of weeds in sunflower agrophytocenoses, (2014-2021)

Class	Family		Genus		Species	
	quantity, per 1 m^2	%	quantity, per 1 m^2	%	quantity, per 1 m^2	%
Dicotyledonous (*Magnoliopsida*)	26	96.3	53	93.5	73	95.0
Monocotyledonous (Liliopsida)	1	3.7	4	6.5	5	5.0
Total	27	100	62	100	78	100

* - difference is statistically significance from check at $P_{0.05}$

Table 3. Spectrum of weeds in sunflower agrophytocenoses by families, (2014-2021).

Botanical family	Quantity of species
Astereae (*Asteraceae)*	18
Cabbage *(Brassicaceae)*	9
Labiate (*Lamiaceae)*	6
Borage (*Boraginaceae)*	4
Legume (*Fabaceae)*	4
Ranunculaceae *(Ranunculaceae)*	3
Amaranthaceae (*Amaranthaceae)*	3
Chenopodiaceae *(Chenopodiaceae)*	2
Euphorbiaceae *(Euphorbiaceae)*	2

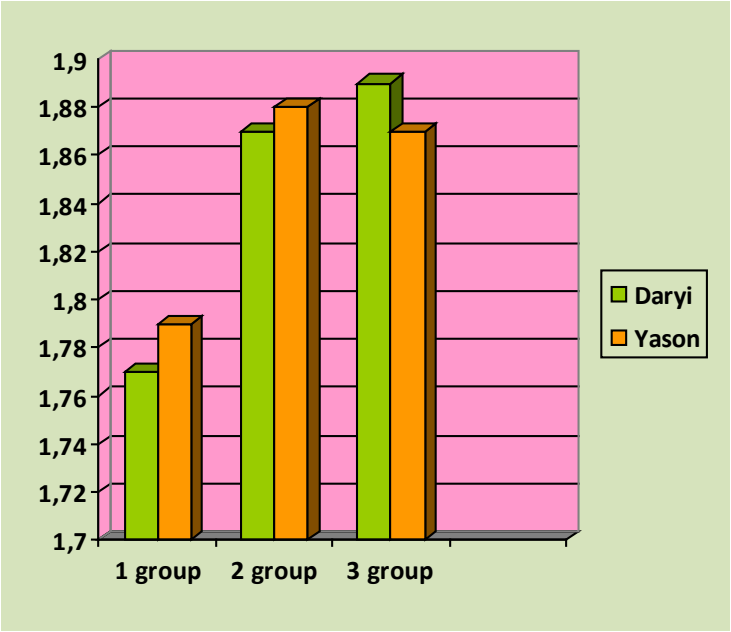

Figure 1. The yield of sunflower hybrids in agrophytocenoses with different species composition of weeds of the Astereae (*Asteraceae)* family (2014-2021).

Table 4. The quantity of weeds in sunflower crops by different methods of basic tillage (average for 2014-2021)

Method of basic tillage	Before harvesting sunflower		
	quantity of weeds per 1 m^2	air-dry weight of weeds, g/m^2	Yield, t/ha
agrocenosis of the hybrid Yason			
plowing (control)	2.1	4.9	2.24
non-moldboard tillage	5.4	14.2	2.11
agrocenosis of the hybrid Daryi			
plowing	2.3	4.8	2.07
non-moldboard tillage	5.5	14.1	1.86

Least Average Difference $(LMD)_{0.05}$ t/ha tillage of soil 0.07 hybrid 0.08

Discussion

Weed control in the agrophytocenoses of sunflower is one of the most important elements of growing technology, which makes it possible to obtain high yields of hybrids and varieties of this crop (Pannacci et al., 2007; Smatana et al., 2014).

Materials from scientific articles by researchers on this problem show that important weeds of the sunflower agrophytocenoses are as follows: Cirsium arvense (L.) SCOP, Elytrigia repens (L.) DESV, Chenopodium album L., Amaranthus retroflexus L., Chenopodium hybridum L., Sinapis arvensis L., Datura stramonium L., Echinochloa crus-galli (L.) P. BEAUV, Persicaria lapathifolia RAF. S. F. GRAY, Persicaria maculata RAF. S. F. GRAY, Fallopia convolvulus L. A. LOVE, Avena fatua L., Convolvulus arvensis L., Tripleurospermum perforatum (L.) SCHULTZ-BIP., Iva xanthiifolia (L.) NUTT., Galinsoga parfiflora CAV. (Kohout, 1993; Rapparini, 2006; Smatana et al., 2008).

Analysis of our results obtained during the examination of sunflower agrocenoses in the fields of field crop rotations showed that in the conditions of the Steppe of Ukraine, and other growing species of weeds were also identified in sunflower agrophytocenoses.

During the research, we observed a weed community in sunflower agrophytocenoses, composed of different species, density and abundance, which was typical of weed flora in the crop rotation fields of the Steppe zone of this region.

The most common were weeds that belonged to different families: bristle-grass green (*Setaria viridis (L.) Beauv*), bristle-grass gray (*Setaria Glauca (L.) Beauv*) – family of Gramineous (*Poaceae*); field pennycress (*Thlaspi arvense L.*), field mustard (*Sinapis arvensis L.*), wild radish (*Raphanus raphanistrum L.*), shepherd's purse (*Capsela bursa pastoris (L.)*), flixweed (*Descurainia sophia L.*) – family of Cabbage (*Brassicaceae*); white goosefoot (*Chenopodium album L.*). redroot (*Amaranthus retroflexus*), prostrate amaranth (*Amaranthus blitoides Wats.)* – family of Amaranth (*Amaranthaceae*) and different types of weeds of the *Asteraceae* family.

Weeds of the families Gramineous (Poaceae), Cabbage (Brassicaceae), of Amaranth (Amaranthaceae) had a less harmful effect on the formation of sunflower yields compared to weeds of the Astereae (Asteraceae) family. The introduction of soil herbicide harness (active ingradient – acetochlor) 2.5 l/ha for pre-sowing cultivation, carrying out pre- and post-emergence harrows, inter-row cultivation of sunflower crops ensured the suppression of weeds of families of Gramineous (Poaceae), Cabbage (Brassicaceae), of Amaranth (Amaranthaceae) by 80.0-90.0% for plowing and non-moldboard processing.

The introduction of soil herbicides did not ensure the suppression of weeds of the Asteraceae family in sunflower agrocenoses, which cause the greatest damage to crops and lead to a significant decrease in yield.

The suppression of weeds of the *Asteraceae* family during the preparation of the soil for sowing and during the growing season was possible only through the correct use of mechanical agricultural methods: pre-sowing cultivation, inter-row cultivation of sunflower crops.

In suppressing weeds in sunflower crops, the application of selective herbicides against weeds is an important agrotechnical technique for growing sunflower from an economic and environmental point of view (Elezovic et al., 1994; Kavdir, 2004).

When the our data obtained at the end of the research are evaluated, the effectiveness suppression of weeds in agrophytocenoses was predetermined by a set of agrotechnical techniques in the technology of growing of the sunflower hybrids.

The use of mechanical agricultural methods in the pre-sowing period and during the growing season ensures the suppression of weeds of the *Asteraceae* family only within 50.0-60.0%.

A higher efficiency of the use of agricultural practices was achieved with a late sowing period and the second inter-row tillage to a depth of 8.0-10.0 cm with hilling plants of sunflower in rows. The use of such a complex of agricultural methods in fields that are clogged forming suckers weeds of the Asteraceae family provides a yield increase of 24.7% compared to the use of agrotechnical methods: sowing sunflower at the recommended time and carrying out the second inter-row cultivation without hilling plants in rows.

Sunflower hybrids of early-ripening and mid-ripening groups turned out to be less competitive in relation to weeds of the first group of the Asteraceae family, which are represented by forming suckers species.

Compared with the weeds of the Asteraceae family of the second and third groups, the weeds of the first group of the same family had a more depressing effect on the growth and development of sunflower plants.

As reported by Smatana (2003), sunflower as a row crop, even at optimal density of plants, does not can compete with the weeds and suppress weeds.

Research conducted in 2014-2021 showed that in the conditions of the Steppe of Ukraine, the competitiveness of sunflower hybrids increased in relation to weeds and was determined by the ability of the each genotype to compete with weeds in the agrophytocenoses, the method the basic tilling, the number of weeds in the agrophytocenoses, the type of weeds.

Field inspection and yield records in the arid conditions of the eastern Steppe of Ukraine show that in the technology of growing sunflower hybrids in crop rotation fields, the early-ripening hybrid Yason, in comparison with the early-medium hybrid Daryi, has a greater competitive ability in relation to weeds of the *Asteraceae* family of the first and second groups.

With the same number of weeds, the first species group of the *Asteraceae* family formed a large vegetative mass in sunflower crops and, before harvesting hybrids, had a greater air-dry mass by 11.1 g/m compared to the weeds of the second and third groups of this family. An increase in the air-dry mass of weeds of the first group by 11.1 g/m^2 led to a decrease in yield in the early ripe hybrid Yason by 0.08-0.10 t/ha, in the early ripe hybrid Daryi by 0.10-0.13 t/ha.

In agrophytocenoses with the species composition of weeds of the second and third groups, a higher competitiveness of sunflower in relation to weeds was observed. In these agrophytocenoses, the hybrids formed the yield at the level of 1.87-1.90 t/ha.

Our research results are consistent with those reported by Papamichali et. al (2002). The decrease in competition with respect to weeds and the yield of sunflower hybrids depended on the species composition of weeds, the density population of the weed, the relative time of their appearance in agrophytocenoses.

If, according to the experiments of Pacanoski, Z. & Mehmeti (2021), Knezevic et. al. (2013), Stefanic et. al. (2023), the large broadleaf weeds Ambrosia artemisiifolia, Chenopodium album and Polygonum lapathifolium, that dominated throughout the experiment, had the greatest negative effect on sunflower yield, significantly suppressing the yield.

In the arid conditions of the Ukrainian Steppe, the first group of weeds small-flowered quick weed (*Galinsoga parviflora Cav.),* common groundsel *(Senecio vulgaris L.)*, acantholeaf thistle (*Carduus acanthoides L.*), common thistle (*Cirsium vulgare (Savi) Ten*), bristly thistle (*Cirsium setosum (Willd) Bess),* creeping thistle (*Cirsium arvense (L) Scop.*) contributed to the greatest reduction in the yield of sunflower hybrids.

Consequently, a multispecies community of weed has different effects on sunflower yield depending on the environmental factors.

Our research in a broader aspect confirms that the yield of sunflower hybrids depended on the species composition of weeds, conditions of environmental, the use the methods of basic tillage, crop care, the reaction of hybrids to growing conditions.

Weeds quickly inhabited sparse crops, plant-free parts of fields in the agrocenoses and formed optically dense sinuses together with agricultural plants. With a decrease in the density of standing sunflower plants to 35-30 thousand/ha in agrocenoses not only increased the clogging of crops by 7.0-11.0% compared to the optimal density of standing plants 40 thousand/ha, but new species of weeds appeared, belonging to the class Dicotyledonous (*Magnoliopsida*) - ragweed.

The basic element of sunflower cultivation technology is the method of basic tillage. Therefore, when developing agricultural method for growing sunflower, it is necessary to take into account the weediness of crops according to different methods of basic cultivation, and in particular, non-moldboard tillage.

A higher level of weediness of sunflower crops, with a predominance of weeds of the family of *Astereae* (*Asteraceae)*, was noted for non-moldboard tillage.

Compared to plowing, non-moldboard tillage did not provide a decrease in weediness of sunflower crops. The use of moldboard-free tillage led to an increase in the quantity of weeds in sunflower agrophytocenoses: by 157.1% in the crops of the early-ripening hybrid Yason and by 139.1% in the crops of the early-medium hybrid Daryi. The air-dry mass of weeds on nonmoldboard tillage increased in the crops of the Yason hybrid by 189.8%, in the crops of the Daryi s hybrid by 193.8%.

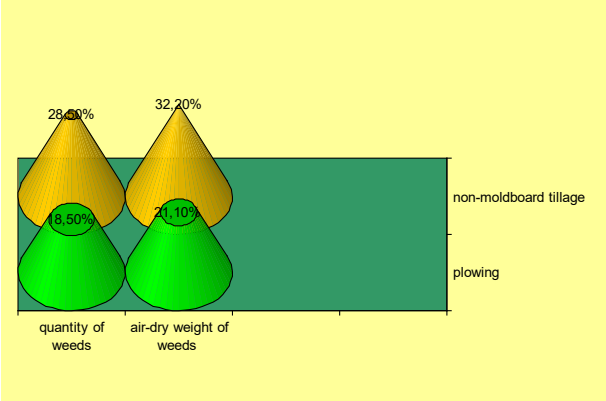

Figure 2. The percentage of weeds of the *Asteraceae* family to the total number of weeds in the agrophytocenosis of the sunflower hybrid Yason before harvesting, (average for 2014-2021).

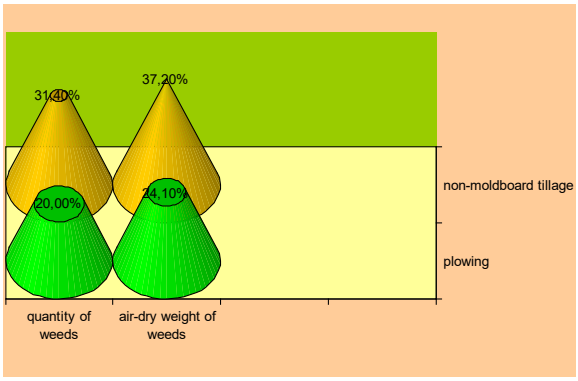

Figure 3. The percentage of weeds of the Asteraceae family to the total number of weeds in the agrophytocenosis of the sunflower hybrid Daryi before harvesting, (average for 2014-2021).

The proportion of weeds of the *Asteraceae* family to the total quantity of weeds in sunflower agrophytocenoses was 18.5 % (agrophytocenose of hybrid Yason) and 20.0% (agrophytocenose of hybrid Daryi) for plowing (Figure 2).

The use of non-moldboard tillage led to an increase in the quantity of weeds of the *Asteraceae* family in agrophytocenoses of hybrids. The proportion of weeds of the Asteraceae family to the total quantity of weeds in sunflower agrophytocenoses was 28.5 % (agrophytocenose of hybrid Yason) and 31.4% (agrophytocenose of hybrid Daryi) for non-moldboard tillage.

An increase in the number of weeds of the *Asteraceae* family led to an increase in the proportion of their air-dry to the total amount of air-dry mass of weeds in the agrophytocenosis before sunflower harvesting.

Before harvesting sunflower, the percentage of air-dry mass of weeds of the Asteraceae family in the agrophytocenosis of the Yason hybrid increased to 20.1% for plowing and up to 32.2% for non-moldboard tillage.

An increase in the number of weeds of the *Asteraceae* family by 10.0%, their share of air-dry mass to the total number of weeds in the agrophytocenoses of the Yason hybrid by 11.1% with non-moldboard tillage led to a decrease in the yield of the hybrid by 5.8%.

The percentage of air-dry mass of weeds of the Asteraceae family in the agrophytocenosis of the Daryi hybrid increased more significantly to 24.1% for plowing and up to 36.4% for non-moldboard tillage (Figure 3).

An increase in the number of weeds of the *Asteraceae* family by 11.4%, their share of air-dry mass to the total number of weeds in the agrophytocenoses of the Daryi hybrid by 13.1% with non-moldboard tillage led to a decrease in the yield of the hybrid by 10.1%.

This was one of the main factors in reducing the yield of sunflower hybrids with the use of non-moldboard tillage.

An increase in the number of weeds, including weeds of the *Asteraceae* family, led to a decrease in the yield of non-moldboard tillage in the Yason hybrid by 0.13 t/ha. In the Daryi hybrid, due to its low competitive ability in relation to weeds, the decrease in productivity for non-moldboard tillage was more significant - 0.21 t/ha.

At the same time, it should be noted that the hybrid Daryi refused to be less competitive in relation to the weeds of the *Asteraceae* family. In the agrophytocenoses of this hybrid, a large quantity of weeds of the *Asteraceae* family and a greater level of yield reduction were noted for both methods of basic tillage. The increase in the number of weeds of the *Asteraceae* family and their air-dry mass for non-moldboard tillage was the main factor in the decrease in yield by 0.21 t/ha.

With almost the same quantity of weeds in the agrofitocenoses of both hybrids for non-moldboard tillage, an increase in the percentage of air-dry mass of weeds of the *Asteraceae* family in the crops of the Daryi hybrid by 5.0%, compared with the crops of the Yason hybrid, led to the formation of the lowest level of productivity in this hybrid 1.86 t ha^{-1}. While at a percentage of the air-dry mass of weeds of the *Asteraceae* e family of 32.2% in the crops of the Jason hybrid, the hybrid formed a higher yield level for non-moldboard cultivation - 2.11 t/ha.

This shows that the Daryi hybrid in dry conditions has less competitive ability in relation to weeds than the Yason hybrid.

Conclusion

The research carried out made it possible to establish the species composition of weeds in the agrophytocenoses of sunflower grown in the conditions of the northern steppe of Ukraine. Studies have established that in sunflower agrophytocenoses, the dominant class of weeds is Dicotyledonous (*Magnoliopsida*). The largest quantity of weeds of the Dicotyledonous (*Magnoliopsida*) class growing in sunflower crops belongs to the families Astereae (*Asteraceae*), *Cabbage* (*Brassicaceae*).

Research has allowed us to establish and identify three species groups of weeds of the Astereae family (*Asteraceae*). In agrophytocenoses, the first group of weeds, which included: small-flowered quick weed (*Galinsoga parviflora Cav.),* common groundsel *(Senecio vulgaris L.)*, acantholeaf thistle (*Carduus acanthoides L.*), common thistle (*Cirsium vulgare (Savi) Ten*), bristly thistle (*Cirsium setosum (Willd) Bess),* creeping thistle (*Cirsium arvense (L) Scop.*), had the most significant and negative impact on the decrease in sunflower yield to the level of 1.77-1.79 t/ha.

The growth of weeds of the first group of the *Asteraceae* family in sunflower agrophytocenoses leads to a decrease in the yield of the early-ripening hybrid Yason by 0.08-0.10 t/ha, by the early-ripening hybrid Daryi by 0.10-0.13 t/ha.

The species composition of weeds depended on the type of weed infestation of crop rotation fields.

The level of yield reduction determined by sunflower was determined by the species composition of weeds, the methods of basic tillage, the competitive ability of hybrids to weeds in agrophytocenoses.

The use of plowing in the technology of sunflower cultivation made it possible to form a maximum yield of 2.07 t/ha for the Daryi hybrid and 2.24 Yason hybrid t/ha, providing more effective weed suppression in sunflower agrophytocenoses with a minimum percentage of air-dry mass of weeds of the Compositae family to the total number of weeds 21.1-24.1%.

The use of non-moldboard tillage, compared with plowing leads to an increase in the air-dry mass of weeds during non-moldboard tillage of 189.8-193.8%.

The increase in the percentage ratio in sunflower agrophytocenoses of the share of weeds of the Asteraceae family by 11.1-13.1% on non-moldboard tillage contributes to a decrease in yield in the early-ripening hybrid Yason per 0.13 t/ha, in the mid-ripening hybrid Daryi per 0.21 t/ha.

The sunflower hybrid Jason has a higher competitive ability in relation to weeds than the hybrid Darius.

In comparison with the agrophytocenoses of the Yason hybrid, in the agrophytocenoses of the Daryi hybrid, a large percentage of the air-dry mass of weeds of the *Asteraceae* family was noted by 3.0% for plowing, by 5.0% for non-moldboard tillage. An increase in the percentage of weeds of the *Asteraceae* family leads to a decrease in the yield of the Daryi hybrid by 0.17 t/ha for plowing, by 0.25 t/ha for non-moldboard tillage.

The level of yield reduction on non-moldboard tillage with an increase in weed infestation of the Asteraceae family in the Yason hybrid was 5.8%, in the Daryi hybrid - 10.1%.

Establishment of weediness of sunflower crops on the background of different methods of basic tillage has also practical consequences. Application of non-moldboard tillage will lead to an increase in the number of weeds in sunflower cultivation on the fields of crop rotations and especially weeds of the first group of small-flowered quick weed (Galinsoga parviflora Cav.), common groundsel (Senecio vulgaris L.), acantholeaf thistle (Carduus acanthoides L.), common thistle (Cirsium vulgare (Savi) Ten), bristly thistle (Cirsium setosum (Willd) Bess), creeping thistle (Cirsium arvense (L) Scop.), which have a strong negative impact on the yield of sunflower hybrids. On fields with a large number of weeds and their air-dry mass it is recommended to grow sunflower hybrid Yason.

Declarations

The author declares no conflict of interest in the design, collection, writing of manuscript and decision to publish this work.

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Effects of Different Types of Pinching in Growth and Yield of Two Varieties of Okra (*Abelmoschus esculentus* L.) in Pokhara, Kaski, Nepal

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ABSTRACT

This study was conducted in Pokhara, Kaski, Nepal in 2023 to investigate the effects of different pinching types and okra varieties on various growth and yield parameters. Treatments were arranged under a two-factor Randomized Complete Block Design (RCBD) with three replications. The treatments includes two okra varieties (Arka Anamika and Parbati) and 4 pinching types (apical bud pinching (P1), ABP along with 1 leaf pinching (P2), and ABP along with 2 leaf pinching (P3) and control (P4)). Parbati has exhibited a higher plant height (80.78 cm) than Arka Anamika (72.35 cm). Similarly, the P4 pinching type resulted in the tallest plant (85.91 cm). The P1 pinching type demonstrated the highest number of primary branches (4.87), while the control plots had the lowest (3.00). Arka Anamika showed a higher leaf count (40.77) than Parbati (37.19). Notably, the P1 recorded the highest leaf count (43.41), followed by P2 (37.19), with the control plots showing the lowest leaf count (32.76). The findings reveal the significant impact of pinching treatments on yield. Pinching type P1 produced the highest yield of 15.45 mt/ha, whereas the control group yielded the lowest at 9.31 mt/ha, which was comparable to the yield observed for pinching type P3 at 10.83 mt ha^{-1}. P1 also exhibited the highest number of pods per plant (15.90). Varieties and pinching methods exhibited notable interactions in average pod weight, diameter, and length. P1 displayed the widest pods (5.97 cm), whereas P2 had the longest (13.18 cm). Additionally, it can be noted that P3 yielded the heaviest pods at 16.16g when compared to P2, which yielded 14.09 g. Pinching treatments significantly influenced number of days to flowering, with P3 demonstrating the longest duration. Economic analysis was performed for evaluating technical efficiency, facilitating informed and sustainable decisions. Economically, P1 demonstrated superior performance, yielding a higher gross return of NPR 540,808.3, a net return of NPR 418,708.3, and a benefit-cost ratio of 4.43.

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Introduction

Okra (*Abelmoschus esculentus* L.) belonging to the family Malvaceae, is an important summer-season vegetable grown in Nepal (Maurya et al., 2013). It is majorly grown in Jhapa, Morang, Saptari, Dhanusha, Mohattari, Rautahat, Bara, Chitwan, and Kailali (Khanal et al., 2020). It is a popular vegetable majorly grown in tropical and subtropical regions, for its delicious and tender green fruits (Pandey et al., 2017). Okra is a vegetable that is low in calories and contains several essential vitamins and minerals. It contains about 33kcal, 7.45g carbohydrates, 1.48g sugars, 3.2g dietary fiber, and 2m proteins per 100g green pod of okra (Kumar et al., 2013). It also contains high fiber content that can help promote healthy digestion and has low cholesterol, reducing the risk of certain chronic diseases, such as heart disease (Gopalan et al., 1971; Kumar et al., 2009). Okra is effective in lowering blood sugar levels and helping those with diabetes. The fiber also aids in maintaining stable blood sugar levels by delaying the absorption of sugar via the intestines (Nguyen et al., 2009). Okra immature fruits, or green seed pods, are eaten as vegetables and can be used fresh or dried, fried or boiled in salads, soups, and stews (Ndunguru & Rajabu, 2004). Okra can be grown in different soil types, but high yields are achieved in well-drained, fertile soils with sufficient organic matter (Akinyele & Temikotan, 2007).

The growth, yield, and quality of okra are hindered by a lack of knowledge regarding optimal management practices and insufficient awareness of its nutritional and health benefits (Bake et al., 2017). Okra productivity in Nepal is 11.54 metric tons per ha (MoALD, 2021) which is lower than the production potential of the okra varieties.

Using low-yielding varieties, improper plant density, improper planting date, soil fertility, fertilizers, and attack of various insect pests, weeds, etc. all impacts vegetable production and productivity in all regions. Agricultural experts are working to formulate environmentally sustainable approaches to boost vegetable crop yields, considering that plant regulators and fertilizers have bad ecological impacts (Kattel et al., 2023). The use of plant regulators and fertilizers increases the cost of production. Therefore, improving cultural practices is crucial for enhancing productivity and the cost of cultivating okra. Besides various agronomic management practices like nutrient management, pinching is also an effective cultural management practice to improve productivity and economy.

Apical bud pinching is a common practice in vegetables like the okra plant which inhibits apical dominance, promotes lateral branch formation, and increases fruit per plant (Gujar & Srivastava, 1972). Apical dominance refers to the process by which the tip or apex of a shoot prevents the growth of secondary or lateral shoots (Cline, 1994). Studies suggest that the plant hormone auxin plays a role in apical dominance. When the apical tip is removed, the source of IAA is eliminated, leading to an increase in the outgrowth of lateral buds (Dun et al., 2006). According to the classical hypothesis, auxin along with secondary messenger, cytokinin regulates shoot branching (Li & Bangerth, 1999; Sachs & Thimann, 1967). The bud transition hypothesis suggests that the bud undergoes different developmental stages, each with varying sensitivity levels or response to long-distance signals, which may include auxin (Shimizu-Sato & Mori, 2001). Pinching is one such method that lets side branches grow by removing the apical buds and some leaves(Rajput et al., 2021). Benefits from pinching also include the management of plant diseases (Jyothi et al., 2018). This technique is commonly employed in various countries for certain okra and cucumber varieties (Kattel et al., 2023). By using this pruning technique, the yield of the plant can be increased (Cline, 1994). Pinching the apical tip of okra at an early stage of growth can increase growth and productivity because it allows enough time for the vegetative parts to regenerate and promotes more branches which increases photosynthetic activity and the accumulation of more photosynthates, thereby increasing seed size and yield (Lakshmi et al., 2015; Patil et al., 2012). Furthermore, pinching of okra 20 days after sowing recorded the highest seed germination, seedling length, and seedling vigor (Chauhan et al., 2022).

The responses of the various varieties to pinching may differ because of their distinct patterns of growth (Malshe & Pethe, 2020). Arka Anamika and Parbati varieties were selected as a recommendation of the National Agriculture Research Council (NARC) due to their adaptability and popularity (Yadav et al., 2023). Much research can be found about the effect of pinching in other vegetables and crops. However, there is limited scientific research on the effect of different types of pinching in okra. Similarly, there is a lack of studies related to the response of okra varieties to different types of pinching. Considering these factors, the study was conducted in Pokhara, Kaski to determine the effects of pinching methods on the growth and yield of okra and find the most responsive okra variety.

Materials and Methods

Experimental location

The experiment site was conducted at Pokhara, Kaski, Nepal from March to July 2023. It is located between 28.194° N latitudes and 84.004° E longitudes and was 822 meters above sea level. The soil property of the experimental site was sandy and alluvial soil with a slightly alkaline pH (7.2). The experimental site has been used for vegetable and rice production. Summer temperatures range between 25 and 35°C. Pokhara and its surrounding areas experience a lot of rain averaging around 4851 mm. The experimental site is illustrated in Figure 1. The meteorological data for Pokhara is depicted as provided by Power NASA in Figure 2.

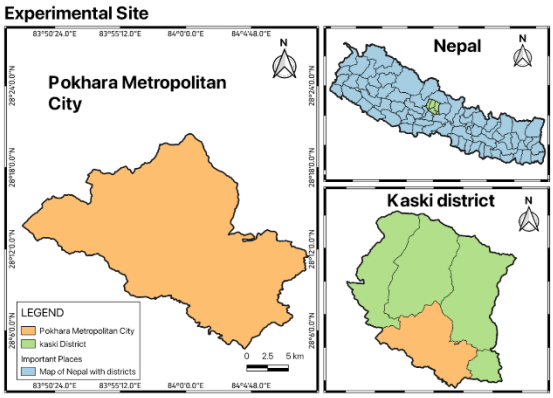

Figure 1. Experimental site

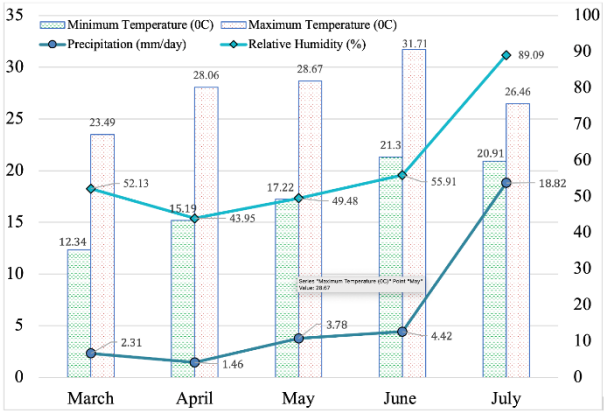

Figure 2. Climate chart of experimental site during study period

Experimental design and treatments

The research experiment was set up in a two-factorial Randomized Complete Block Design (RCBD) with three replications and eight treatments. Two okra varieties (Arka Anamika and Parbati) were used in the study. The plot size used was 1.5m * 2m. Row to row distance of 50 cm and Plant to Plant distance of 30 cm were maintained. Each plot had twenty plants maintained and a total of 24 plots in the study. From each plot, five plants were sampled. Land preparation was done by using power tillage and a raised bed was prepared by using helping hands. Sowing of seed was done on April 7, where row-to-row distance of 50 cm and plant-to-plant distance of 30 cm was maintained. The detail of treatment is shown in Table 1.

Table 1. Treatments details used during research process.

Varieties (Factor 1)	Pinching types (Factor 2)
V1 = Arka Anamika V2= Parbati	P1 = Apical Bud Pinching (ABP) P2 = ABP + 1 leaf pinching P3 = ABP + 2 leaf pinching P4 = Control
Treatments	Combinations
Treatment 1	V1P1
Treatment 2	V1P2
Treatment 3	V1P3
Treatment 4	V1P4
Treatment 5	V2P1
Treatment 6	V2P2
Treatment 7	V2P3
Treatment 8	V2P4

Plant Management Practices

Okra seeds to be sown were soaked overnight, treated with SAAF fungicide (Carbendazim 12% + Mancozeb 63% WP), and sown at a depth of 3-4 cm. The amount of fertilizer was calculated based on the recommended rate of NPK for okra in Nepal. 600 kg FYM per ropani, 6 kg Urea per ropani, 4 kg DAP per ropani, and 2kg MOP per ropani are recommended doses of NPK (MoALD, 2022). The full dose of DAP and MOP and a half dose of urea were applied at the time of sowing. The remaining dose of urea was top-dressed in two equal splits at 30 and 40 DAS. The various pinching treatments were manually performed 20 days after sowing. To improve the planting condition mulching was used to suppress weed growth reduce the amount of time and effort needed for manual weeding and improve soil moisture. Similarly, irrigation was given at 4-5 days intervals during summer and manual weeding was also done. Appropriate management and control techniques were used depending on the disease and pest affecting the plant. The field was treated with Noorani 505 (Chlorpyrifos 50% + Cypermethrin 5% EC) to manage jassid infestations.

Data Collection and Measurement

Various sample techniques were used to measure each crop's growth, yield, and yield components from each plot across the treatment level. Five plants from each plot were selected randomly and were marked as sample plants. The treatments were given 20 DAS (days after sowing) to each plot and vegetative data were collected every 10 DAT (days after treatment). The reproductive data were collected after flowering was observed. Harvesting was done at intervals of four days. The following parameters were studied during the study period.

Vegetative Parameters

Plant height (cm) was observed by measuring the length of the main stem from the base (the point of emergence of the plant to the top of the main stem on each sample pant with the help of a measuring scale. The number of leaves per plant was measured by counting the number of leaves (green leaves) excluding the dying yellow and emerging leaves from the sample plant. The number of branches per plant was measured by counting the number of branches from each sample plant. The vegetative parameter measurements were taken at 10-day intervals and were averaged for each day of observation.

Reproductive Parameters

Pod length (cm) was taken as the average fruit length measured with the help of a scale and rope. Pod diameter (cm) was obtained by calculating the circumference from the mid-length of each fruit with the help of rope and measuring scale. The number of fruits per plant was recorded as the average of the cumulative number of fruits in all picking of selected plants of a plot at the marketable stage for each treatment. The number of days to flowering was observed by counting days from the date of treatment to the first flowering appeared in each plot and the mean was recorded. Individual pod weight (g) of randomly selected pods in each treatment was measured with the help of highly precise electrical balance and the mean was calculated. Yield (mt ha^{-1}) was calculated by multiplying the fruit yield per plant by the total number of plants in one hectare.

Economic parameters

Cost of cultivation

All the cost of cultivation was worked out based on costs incurred according to the prevailing market price for different inputs, laborers, machines, fertilizers, and others. Only variable costs were included in the total costs section, for being a single-season crop.

Total cost = Cost of input × amount of input

Gross returns

The total monetary value of the okra on selling based on the prevalent average market was calculated.

Total income = P ×Y

Where, P = Rate/Farm gate price and Y = Yield

Net returns

Net returns (NRs. ha^{-1}) for each plot were calculated by deducting the cost of cultivation from the gross return obtained.

Net Profit = Gross Returns-Total Costs

Benefit-cost ratio

The benefit-cost ratio (B: C ratio) was calculated by dividing the gross return with the cost of cultivation. For a business to be feasible the B: C ratio of the business should be more than 1. If the BC ratio is less than 1, then the business is at a loss and the investor should not invest in that business.

Benefit Cost Ratio =Gross Returns/total cost

Statistical Analysis

Data collected from the sample plant was entered systemically in MS Excel (Office package 2016). Statistical test such as Analysis of Variance (ANOVA) was carried out by using R-studio (version 4.3.2). Mean comparison was done by using Duncan's Multiple Range Test (DMRT) to find out significant differences between the mean values at a 5% level of significance.

Results and Discussion

Vegetative Parameters

Various effects of treatments were observed for various vegetative parameters of okra. The result of the analysis of variance showed the following effects.

Plant Height

The effect of different pinching types and varieties on okra plant height is shown in Table 2. Plant height showed a significant difference for different pinching types except at 10 DAT whereas the difference was significant in varieties at 10 DAT ($p<0.01$) and 50 DAT ($p<0.05$). The highest height was observed in Parbati (80.78 cm) at 50 DAT. P4 pinching type (control plots) showed the highest plant height (85.91 cm) at 50 DAT ($p<0.05$). Similarly, the highest height was observed in control plots (P4) after 10 DAT, whereas at 50 DAT, P1 (75.35), P2 (73.68), and P3 (71.26) showed statistically similar plant height. The result suggests that the plant height slows down after pinching. This decrease in plant height is due to the redirection of auxin by pinching, which leads to the development of lateral branches and ultimately results in a decrease in the overall height of the plant (Deshmukh et al., 2022). A similar result was observed by (Sahu & Biswal, 2020) and (Ali et al., 2021) which also reported higher heights of okra plants that were not pinched. Results showed no significant interaction effect between different varieties and the pinching types for plant height. A similar result was reported by (Kattel et al., 2023).

Number of Leaves Per Plant

The number of leaves per plant was found to be significantly affected by varieties in all observations and pinching types in all observations except at 10 DAT (Table 3). Significant interaction among the varieties and pinching types was not observed for the number of leaves per plant. Arka Anamika showed a significantly higher number of leaves per plant than Parbati during all the observations. The highest number (40.77) of leaves per plant was observed in Arka Anamika at 50 DAT at ($p<0.001$) level of significance. After 20 DAT P1 pinching level (18.37) showed a significantly ($p < 0.05$) higher number of leaves which was statistically at par with P2 (16.12). The number of leaves was observed significantly ($p < 0.001$) higher in P1 (29.15) and a significantly ($p < 0.001$) lower number of leaves was observed in P4 (20.92) at 30 DAT. A similar result was also seen at 40 DAT. The highest number of leaves (43.41) was observed in the P1 pinching type and the lowest number of leaves (32.76) per plant was observed in the P4 pinching type at 50 DAT. Results suggested that control plots showed a lower number of leaves per plant compared to pinching treatment which was also observed in okra (Kattel et al., 2023) and (Sahu & Biswal, 2020). Similarly, pinching of the apical buds on the main stem of okra resulted significant increase in the number of leaves per plant and the leaf area (Rajappa et al., 2020). Employing the pinching technique increases the number of branches per plant, consequently resulting in a higher leaf count per plant in pinched plants which was also reported (Olasantan & Salau, 2008), in bottle gourd (AN et al., 2017) and field bean (Kumar et al., 2018).

Table 2. Effect of varieties and pinching types on plant height in okra

Treatments	Plant height(cm)				
	10 DAT	20 DAT	30 DAT	40 DAT	50 DAT
Varieties					
Arka Anamika	12.17^{b}	20.43	41.17	65.58	72.35^{b}
Parbati	14.30^{a}	20.63	41.59	69.98	80.78^{a}
LSD (0.05)	1.364	2.21	4.37	6.48	6.99
SEM (±)	0.45	0.73	1.44	2.14	2.30
F-Test	**	ns	ns	ns	*
Pinching types					
P1	13.04	19.71^{bc}	38.95^{b}	67.92^{b}	75.35^{b}
P2	12.44	21.15^{ab}	40.45^{b}	63.41^{b}	73.68^{b}
P3	13.09	17.71^{c}	37.49^{b}	60.01^{b}	71.26^{b}
P4	14.37	23.56^{a}	48.63^{a}	77.81^{a}	85.91^{a}
LSD (0.05)	1.92	3.13	6.18	9.17	9.88
SEM (±)	0.63	1.03	2.03	3.02	3.25
F-Test	ns	**	**	**	*
CV (%)	11.76	12.33	12.07	11.01	10.42

Means followed by the same letter(s) in a column are not significantly different by LSD 0.05 level by DMRT. DAT = Days after Treatment, SEM (±) = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variance, ns = non-significant and *Significant at 5% ($p<0.05$), **Significant at 1% ($p<0.01$),***Significant at 0.1% ($p<0.001$)

Table 3. Effect of varieties and pinching type on number of leaves per plant in okra

Treatments	Number of leaves				
	10DAT	20 DAT	30 DAT	40 DAT	50 DAT
Varieties					
Arka Anamika	8.94[a]	16.82[a]	25.89[a]	34.36[a]	40.77[a]
Parbati	7.67[b]	14.86[b]	22.76[b]	29.35[b]	37.19[b]
LSD (0.05)	0.89	1.87	1.99	2.29	2.86
SEM (±)	0.29	0.61	0.65	0.75	0.94
F- test	**	*	**	***	***
Pinching types					
P1	8.23	18.37[a]	29.15[a]	38.42[a]	43.41[a]
P2	8.11	16.12[ab]	24.43[b]	31.47[b]	37.19[b]
P3	7.67	15.07[b]	22.81[bc]	30.18[bc]	35.50[bc]
P4	9.12	13.81[b]	20.92[c]	26.98[c]	32.76[d]
LSD (0.05)	1.26	2.65	2.82	3.24	4.05
SEM (±)	0.42	0.87	0.93	1.06	1.33
F- Test	ns	*	***	***	***
CV (%)	12.27	13.52	9.38	8.82	8.79

Means followed by the same letter(s) in a column are not significantly different by LSD 0.05 level by DMRT. DAT = Days after Treatment, SEM (±) = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variance, ns = non-significant and *Significant at 5% ($p<0.05$), **Significant at 1% ($p<0.01$),***Significant at 0.1% ($p<0.001$)

Table 4. Effect of varieties and pinching type on number of primary branches in okra

Treatments	Number of primary branches				
	10DAT	20 DAT	30 DAT	40 DAT	50 DAT
Varieties					
Arka Anamika	1.24	1.90	3.09	3.77	4.22
Parbati	1.34	2.09	2.91	3.68	3.92
LSD (0.05)	0.32	0.34	0.43	0.51	0.58
SEM (±)	0.10	0.11	0.14	0.17	0.19
F- test	ns	ns	ns	ns	ns
Pinching types					
P1	2.05[a]	3.10[a]	3.85[a]	4.67[a]	4.87[a]
P2	1.62[a]	2.37[b]	3.32[ab]	3.89[b]	4.44[ab]
P3	1.08[b]	1.76[c]	3.0[b]	3.55[b]	3.97[b]
P4	0.40[c]	0.76[d]	1.87[c]	2.79[c]	3.00[c]
LSD (0.05)	0.45	0.48	0.61	0.72	0.81
SEM (±)	0.15	0.16	0.20	0.23	0.26
F- Test	***	***	***	***	**
CV (%)	28.35	19.45	16.52	15.73	16.16

Means followed by the same letter(s) in a column are not significantly different by LSD 0.05 level by DMRT. DAT = Days after Treatment, SEM (±) = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variance, ns = non-significant and *Significant at 5% ($p<0.05$), **Significant at 1% ($p<0.01$),***Significant at 0.1% ($p<0.001$)

Primary Branches Per Plant

The primary branch per plant was not found significantly affected by plant varieties. However, the primary branch per plant was found significantly affected by pinching types in all observations (Table 4). Significant interaction among the varieties and pinching types was not observed for the number of primary branches. The highest number (4.87) of primary branches was found in the P1 pinching type at ($p<0.01$) level of significance which was statistically at par with the P2 pinching type (4.44). The lowest number of primary branches (3.00) was found in the P4 pinching type (control plots) at 50 DAT. A similar type of observation was also seen in 10 DAT, 20 DAT, 30 DAT, and 40 DAT. The result of the analysis suggests that pinching promotes branches in pinched plants. A similar result was observed by (Rajappa et al., 2020) and (Deshmukh et al., 2022). The increase in the number of branches in pinched plants is primarily due to the reduction of apical dominance, which halts vertical growth and accelerates the development of productive branches. Consequently, this enhances photosynthetic activity, the accumulation of photosynthetic materials, and leads to increased fruit production and yield (Lakshmi et al., 2015). Similarly, significant differences were observed in the shoot branch and top fresh weight at different times of pinching in okra (Kim et al., 2015). Finally, a higher number of branches due to pinching was also reported in bottle gourds (AN et al., 2017) and marigolds (Abbas, 2018).

Reproductive data

Days to flowering

Days to flowering were found significant for different pinching types at ($p< 0.01$) level of significance but were not found significant for different varieties (Table 9). The analysis didn't show significant interaction between pinching types and two varieties for days to flowering. Arka Anamika and Parbati didn't show significant differences for days to flowering. The highest days to flowering (52.29 days) were observed for P2 (apical bud pinching and two leaf pinching) and the lowest days to flowering (43.62 days) were observed in P4 i.e. control

plots. Results of the analysis suggested pinched plants exhibited delayed flowering, possibly because the removal of the apical portion hindered the process by removing the source of Indole 3-Acetic Acid (IAA). With lower concentrations of IAA, the initiation of lateral branches occurs which requires additional time to mature sufficiently for flowering to begin (Ali et al., 2021). The practice of pinching has previously been documented to cause delayed flowering in various crop species, such as carrots (Shah, 2019) and bottle gourd (AN et al., 2017).

Pod diameter (cm)

Pod diameter (cm) was found significant at ($p< 0.05$) level of significance for different varieties and was also significant at ($p< 0.001$) level of significance for different pinching types (Table 9). Parbati (5.59 cm) showed maximum pod diameter and Arka Anamika (5.30 cm) showed lowest pod diameter. This difference in average pod diameter in okra varieties might be due to variation in their genotype and their adaptability to environmental conditions. A similar type of result was observed in okra varieties (Dash & Rabbani, 2013). Similarly, the highest pod diameter (5.97 cm) was observed for P1 (apical bud pinching) whereas the lowest pod diameter (5.00 cm) was observed for P4 (non-pinched). The increase in pod diameter could be attributed to the greater presence of branches and leaves, along with the higher availability of photosynthates moving from the source to the sink (Shah, 2019). As a result of the pinching technique, a state of hormonal and nutritional equilibrium is achieved, resulting in the production of larger-sized fruits.

Significant interaction was observed at ($p < 0.05$) level of significance between varieties and pinching types for the average pod diameter (Table 5). The highest pod diameter was observed in Arka Anamika (5.91 cm) at the P1 pinching type which was seen as statistically similar to the P1 pinching type treatment in Parbati (6.04 cm). The lowest pod diameter was observed in Arka Anamika (4.64 cm) with P4 pinching type.

Pod length (cm)

Pod lengths were observed to be significant at ($P < 0.01$) level of significance for different varieties and were also observed to be significant at ($P < 0.05$) level of significance for different pinching types (Table 9). Arka Anamika (12.63 cm) showed the highest average pod length. The variation in average pod length among various okra varieties can be attributed to differences in their genetic characteristics and their varying ability to adapt to environmental conditions.

Table 5. Pod diameter as influenced by the interaction pinching types and varieties of okra

Treatments	Pod diameter (cm)			
	P1	P2	P3	P4
Arka Anamika	5.91^{a}	5.58^{ab}	5.07^{cd}	4.64^{d}
Parbati	6.04^{a}	5.30^{bc}	5.66^{ab}	5.37^{bc}
LSD(0.05)	0.42			
SE(±)	0.14			
F- Probability	*			
CV%	4.74			

Means followed by the same letter(s) in a column are not significantly different by LSD 0.05 level by DMRT. DAT = Days after Treatment, SEM (±) = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variance, ns = non-significant and *Significant at 5% ($p<0.05$), **Significant at 1% ($p<0.01$),***Significant at 0.1% ($p<0.001$)

Table 6. Pod length as influenced by the interaction of pinching types and varieties of okra

Treatments	Pod length (cm)			
	P1	P2	P2	P3
Arka Anamika	12.55^{b}	14.75^{a}	11.43^{bc}	11.80^{bc}
Parbati	11.78^{bc}	11.62^{bc}	11.47^{bc}	10.96^{c}
LSD(0.05)	1.17			
SE(±)	0.38			
F- Probability	*			
CV%	5.58			

Means followed by the same letter(s) in a column are not significantly different by LSD 0.05 level by DMRT. DAT = Days after Treatment, SEM (±) = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variance, ns = non-significant and *Significant at 5% ($p<0.05$), **Significant at 1% ($p<0.01$),***Significant at 0.1% ($p<0.001$)

Table 7. Individual pod weight as influenced by the interaction of pinching types and varieties of okra

Treatments	Individual pod weight (grams)			
	P1	P2	P2	P3
Arka Anamika	11.22^{c}	15.04^{ab}	17.93^{a}	10.53^{c}
Parbati	14.48^{b}	14.95^{ab}	14.04^{b}	12.36^{bc}
LSD(0.05)	2.97			
SE(±)	0.98			
F- Probability	*			
CV%	12.26			

Means followed by the same letter(s) in a column are not significantly different by LSD 0.05 level by DMRT. DAT = Days after Treatment, SEM (±) = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variance, ns = non-significant and *Significant at 5% ($p<0.05$), **Significant at 1% ($p<0.01$),***Significant at 0.1%($p<0.001$)

Table 8. Reproductive parameters as influenced by varieties and pinching types in okra

Treatments	Days to flowering	Pod Diameter (cm)	Pod Length(cm)	Pods/plant	Pod weight (g)	Yield (mt/ha)
Varieties						
Arka Anamika	48.04	5.30^{b}	12.63^{a}	11.86	13.68	10.90
Parbati	48.75	5.59^{a}	11.46^{b}	14.05	14.04	12.96
LSD (0.05)	2.76	0.21	0.58	2.29	1.48	2.88
SEM (±)	0.91	0.07	0.19	0.80	0.49	0.95
F-probability	ns	*	**	ns	ns	ns
Pinching types						
P1	47.67^{b}	5.97^{a}	12.17^{b}	15.90^{a}	12.83^{b}	15.45^{a}
P2	50.01^{ab}	5.44^{b}	13.18^{a}	13.42^{ab}	14.09^{a}	12.14^{ab}
P3	52.29^{a}	5.36^{b}	11.45^{b}	11.55^{b}	16.16^{a}	10.83^{b}
P4	43.62^{c}	5.00^{c}	11.38^{b}	10.95^{b}	11.44^{b}	9.31^{b}
LSD (0.05)	3.90	0.30	0.83	3.03	2.10	5.77
SEM (±)	1.28	0.10	0.27	1.14	0.69	1.34
F-Probability	**	***	*	*	**	*
CV (%)	6.51	4.74	5.58	21.57	12.26	27.64

Means followed by the same letter(s) in a column are not significantly different by LSD 0.05 level by DMRT. DAT = Days after Treatment, SEM (±) = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variance, ns = non-significant and *Significant at 5% ($p<0.05$), **Significant at 1% ($p<0.01$),***Significant at 0.1%($p<0.001$)

Table 9. Economic parameters as affected by pinching types and varieties of okra

Treatments	Total cost of cultivation (NPR ha^{-1})	Gross return (NPR ha^{-1})	Net return (NPR ha^{-1})	B:C ratio
Varieties				
Arka Anamika	122100	381791.7	259691.7	3.12
Parbati	122100	453658.3	331558.3	3.71
LSD (0.05)	0	101131.5	101131.5	0.82
SEM (±)	0	33341.66	33341.66	0.27
F-probability	ns	ns	ns	ns
Pinching types				
P1	122100	540808.3^{a}	418708.3^{a}	4.43^{a}
P2	122100	425075.0^{ab}	302975^{ab}	3.48^{ab}
P3	122100	379166.7^{b}	257066.7^{b}	3.10^{b}
P4	122100	325850.0^{b}	203750^{b}	2.66^{b}
LSD (0.05)	0	143021.5	143021.5	1.17
SEM (±)	0	47152.23	47152.23	0.38
F-Probability	ns	*	*	*
CV %	0	27.64	39.06	27.65

Note: 1USD (United States Dollars)= 134.29 NPR (August 12, 2024, exchange rate), Means followed by the same letter(s) in a column are not significantly different by LSD 0.05 level by DMRT. DAT= Days after Treatment, SEM (±) = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variance, NPR = Nepalese Rupee, ns = non-significant and *Significant at 5% ($p<0.05$), **Significant at 1% ($p<0.01$),***Significant at 0.1% ($p<0.001$)

Highest pod length (13.18 cm) was observed in P2 (apical bud + 1 leaf pinching). Pinched okra gave higher length fruits than non-pinched okra was also reported in okra (Kattel et al., 2023). The positive impact of pinching on pod size could be linked to the generation and movement of nutrients from the source to the sink and a higher number of leaves producing a higher amount of photosynthate, particularly carbohydrates which are transported to the sink, leading to the development of longer pods (Sowmya et al., 2017).

Significant interaction was observed at ($p < 0.05$) level of significance between varieties and pinching types for the average pod length (Table 6). Pod length as influenced by the interaction of varieties and pinching treatment was observed highest in Arka Anamika with P2 pinching treatment (14.75 cm) followed by P1 pinching treatment (12.55 cm). The lowest Pod length was seen in the interaction of Parbati and control pinching treatment (10.96 cm).

Pods per plant

Pods per plant were not observed to be significant between the two varieties but were observed to be significant at ($p < 0.05$) level of significance among different pinching types (Table 9). The highest pods per plant were observed in the P1 pinching type (15.90). A higher number of pods per plant was observed in pinched plots than in control plots. The same finding was reported by (Sahu & Biswal, 2020). Pinched plants exhibited a higher number of pods compared to those that were not pinched. Plants with an increased number of lateral branches displayed robust vegetative growth, leading to enhanced photosynthetic efficiency (Aikins et al., 2017). Similar to the results obtained in this research, the positive impact of pinching on reproductive growth has been noted in fenugreek (Vasudevan et al., 2008). The interaction between two varieties and four types of pinching did not show a significant interaction on the number of pods per plant.

Individual pod weight (g)

Individual pod weight (g) was observed to be significantly influenced by different pinching types at ($p < 0.01$) level of significance but was not observed significant difference among the two varieties (Table 9). The highest individual pod weight was observed in plots of the P3 pinching type (16.16 g) followed by the P2 pinching type (14.09 g). Mostly pinched plots gave higher average pod weight than non-pinched i.e. control plots. It was reported that in pinched plants, there is a greater presence of lateral branches, which are characterized by a higher leaf count and increased photosynthate production (Ali et al., 2021). The pinching technique results in the accumulation of more photosynthate in the sink, which is advantageous for producing heavier pea pods (Singh & Devi, 2006). Our findings were also consistent with the finding reported in Fenugreek by (Vasudevan et al., 2008). Similar beneficial effect was also observed in Okra (Sajjan et al., 2002). There was seen significant interaction at ($P < 0.05$) level of significance between varieties and pinching type for individual pod weight in okra Pokhara, Nepal 2023 (Table 7). The highest individual pod weight as influenced by okra varieties and pinching treatments was seen in Arka Anamika and P3 pinching treatment (17.93 g). The lowest individual pod weight was seen in Arka Anamika with P1 (11.22 g) which is seen statistically similar to Arka Anamika with P4 pinching treatment (10.53 g).

Yield (mt ha^{-1})

Yield (mt ha^{-1}) is found significantly influenced by different pinching methods but not significant in the case of variety (Table 9). The highest yield was observed in P1 i.e. Apical bud pinching (15.45 mt ha^{-1}) followed by P2 (12.14 mt ha^{-1}). The mean yield was observed at 11.93 mt ha^{-1}. Pinching causes the production of more lateral branches which increases photosynthesis and increases productivity. A similar result was observed in okra (Kattel et al., 2023) and by (Sahu & Biswal, 2020). Pinching techniques have previously been documented as advantageous for enhancing yield characteristics in various crop species like tomatoes (Tswanya & Olaniyi, 2016), bottle gourd (Naafe et al., 2022), and fenugreek (Sowmya et al., 2017).

Economic Analysis

The economic analysis was conducted by considering the production costs associated with each treatment, along with the resulting marketable yield at current unit prices.

Cost of Cultivation (NRs)

The cost of cultivation includes all the tentative working costs incurred in okra cultivation which was calculated in terms of cost per hectare. The cost of cultivation was similar for all the varieties and all the pinching types were NRs.122100ha^{-1}.

Gross Returns (NRs)

The overall financial worth of the primary product and any secondary products derived from the crop is referred to as gross return. This value was computed using the current average market conditions. Significant effect of pinching treatments in gross return but no significant effect of varieties on gross return was observed (Table 9). The highest gross return (NRs. 540808.3) was observed in P1 (apical bud pinching) closely followed by P2 (NRs.425075.0). Lowest gross return (NRs. 325850) was observed in P4 (control plots) which was statistically similar to other except P1 pinching type.

Net returns (NRs)

Net return is the gross return excluding the cost of cultivation. The table showed there was no significant difference in net return in varieties and showed a significant difference between different pinching treatments (Table 9). The highest net return (NRs. 4, 18,708) was observed in P1 closely followed by P2 pinching type (NRs. 3, 02,975). The lowest net return was observed in P4 (NRs. 2, 03,750) which was statistically similar to others except P1 pinching type.

Benefit-cost ratio (B: C ratio)

The benefit-cost ratio (B: C) is described as the return generated for each rupee invested. The B: C ratio was found significant for the pinching treatments and insignificant for the varieties (Table 9). The highest B: C ratio (4.43) was observed in the P1 pinching type closely followed by the P2 pinching type (3.48). The lowest net return (2.66) was observed in P4 (control plots) which was statistically similar to others except P1 pinching treatment.

Conclusion

The study brought some important information about the effect of different pinching types and varieties on the growth and yield of okra. Yield and yield-related parameters of okra were significantly affected by various pinching types. The application of the pinching treatment types mentioned increased the number of primary branches, total number of fruits per plant, and yield performance of okra. The application of pinching types or methods in two varieties of okra, Parbati showed higher plant height, and Arka Anamika showed a higher number of leaves but showed similar days to flowering, the total number of pods per plant, and yield. Economically two varieties also didn't show any significant difference but showed significant differences for pinching types. Results revealed no variation among varieties for the productivity of okra. Based on the findings, the use of apical bud pinching on okra is recommended as a better practice than apical bud and leaf pinching to increase productivity.

Declarations

Author Contribution Statement

Prajjwal Koirala: Devised and designed the experiments; Performed the experiments; Analyzed and interpreted the data; materials, analysis tools or data; Wrote the paper.

Rijwan Sai: Analyzed and interpreted the data; materials, analysis tools, or data; Wrote the paper.

Pratikshya Subedi: Data collection; wrote the paper

Chiranjibi Khadka: Performed the experiments; Data collection; wrote the paper

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Declaration of Competing Interest

The authors declare no conflict of interest.

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An Assessment of Nutritional Deficiency Symptoms in the Tea Plant (*Camellia sinensis* L.) Through Field Survey

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ABSTRACT

The most important factor in both plant development and productivity, which mostly depends on nutrient availability in the soil and environment, is the constituents of soil nutrients. Soil is always losing its nutrients by leaching, surface runoff as well as through harvesting and cultural operations like: pruning. For maintaining the balance of agricultural ecosystem fertilizer application is necessary to improve soil condition and gain better yield. In case of tea industry for maintaining better and uniform production applying fertilizer is a widespread management technique in worldwide. Tea requires a lot of macro and micronutrients for growth because it cannot be grown without the usage of fertilizer and other nutrient supplies. The purpose of this field survey was to ascertain the nutritional condition of tea leaves as well as the signs of nutrient deficiencies in tea plants. In this study, deficiency symptoms of the essential nutrients were found out at different tea estates of Moulvibazar and Sylhet districts as well as photographs were taken. Photographs of the nutrient deficient tea plants were correlated with the established symptoms. The range of total nitrogen, phosphorus, potassium, calcium, magnesium and zinc content in the collected tea leaf samples were 2.95- 5.18%, 0.28- 0.49%, 0.56-1.88%, 0.12-0.49%, 0.07-0.08% and 0.002- 0.004%, respectively.

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Introduction

Tea (*Camellia sinensis*) is an essential beverage cash crop planted under acidic soil conditions, which considerably contributes to the economies of various tea-growing countries in Asia, Africa, and Europe like Bangladesh, India, Sri Lanka, Kenya, Ethiopia, Georgia and Germany etc. According to De Costa et al. (2007), the tea plant can grow as high as 15 meters in the wild, but in cultivation, the crop is kept at 0.6m to 1.0m tall to make leaf harvesting easier. The soils condition differs from one country to another for tea plantation and the most important character is soil pH (Hajiboland, 2017). Tea grows best in a pH range of 4.5 to 5.8 (Zohora et al., 2022). The ideal soil conditions for tea growing are well-drained, deep, and well-aerated soil with 1% organic matter. (De Silva, 2007; Zohora et al., 2022). The other characteristics of soil including the soil's depth (less than 50 cm), slope of the field, graveliness (more than 50%) and rockiness (20%) of the soil have to be considered suitable for tea production with economic viability (Hajiboland, 2017).

Plant productivity is significantly influenced by the amount and caliber of nutrients present in the soil. The continuous removal of leaves from the soil during the tea-growing process gradually reduces the nutrients in the soil, requiring the plant to replenish those minerals (Tabu et al., 2015). Therefore, utilization of organic and inorganic fertilizers is essential. Chemical fertilizers are necessary for increased production and they can also increase both the quality and quantity of tea. A chemical element known as a “plant nutrient” is necessary for the vegetative and reproductive growth of plants. A plant cannot complete the vegetative or reproductive stages of its life cycle if it is lacking in a critical ingredient. This kind of shortage is particular to the element and can only be avoided by providing it. The element directly affects the plant's nourishment. Short supply of the essential nutrients results abnormal growth with deficiency symptoms of plants due to the result of the disruption of metabolism (Mengel & Kirkby, 2001). Therefore, to achieve higher tea production it is very important to know the functions of different nutrient elements, their status, deficiency symptoms, remedial measures of the deficiency of nutrients and critical limits in tea leaves which are presented in this article.

Materials and Methods

In 2023, a field survey was conducted in four tea plantations, including Marina, Saif, and Mazdehee tea estate in Moulvibazar district and Monipur tea estate in Sylhet district. Different nutrient deficiency symptoms of tea plants were identified in the tea field and photographs were captured. While conducting a field survey, 27 fresh tea leaf samples were taken from various tea fields on the estates for chemical analysis to measure nutritional content. Samples of fresh tea leaves were collected, cleaned in distilled water, and allowed to air dry. After that, leaf samples were oven dried for 48 hours at 80°C (Huq & Alam, 2005) and make them fine powder by using grinder. The leaf samples were digested by the nitric acid - perchloric acid (Huq & Alam, 2005). Using the Micro Kjeldahl steam distillation method, the total nitrogen was measured (Huq & Alam, 2005). A spectrophotometer (JENWAY 6300) was used to measure total phosphorus using the blue color method (Huq & Alam, 2005). The total potassium, calcium, magnesium, and zinc were measured using an Atomic Absorption Spectrophotometer (AAS) (Analytikjena, Model: novAA 400P).

Statistical Analysis

Microsoft Excel and IBM SPSS 20 were used to record and statistically analyze all of the data. One-way ANOVA, or the Analysis of Variance of Simple Classification, was used to evaluate the data, and treatments that were found to be significant were further examined using Tukey's post hoc test at the 5% level.

Results and Discussion

Plant Nutrient Elements

Even though there are more than 90 components in a plant, just 16 are thought to be necessary for healthy growth and development. Water or air is the sources of carbon, hydrogen, and oxygen. According to Ahmed et al. (2018), soil nutrient solutions provide the remaining 13 elements. The "macronutrients," or elements needed in significant amounts, typically build up in plant tissues to levels of 1 mgg^{-1} dry weight and higher. Examples of these elements are calcium, magnesium, potassium, phosphorus, sulfur, nitrogen, and sulphur. Plants require small amounts of "micronutrients," which can accumulate to less than 100 μgg^{-1} dry weight. Examples of these elements include iron, zinc, manganese, copper, molybdenum, nickel, boron, and chlorine. (Hajiboland, 2018).

Micronutrients are also known as trace elements which have specific functions connected with enzymes and co-enzymes**.** From the research discussion of Hajiboland (2018) and Ahmed et al. (2018) the classifications of essential elements can be presented in figure no 1.

Major Elements

Nitrogen (N)

Following carbon, nitrogen (N) is the most mobile and inadequate mineral element in soil and is essential to plant growth and development (Hawkesford et al., 2012). Nitrogen feeding increases tea productivity in a variety of environmentally advantageous situations without having any negative impacts from high N supply (Owuor, 1997). According to Khan et al. (2013), the critical limit for total nitrogen in tea soil is 0.1%. N accounts for 1% to 5% (10-50 mgg^{-1} dry weight) of total dry matter in plants. It promotes vegetative growth of tea plants and due to being constituent of protein, nucleic acid and chlorophyll it enhances metabolic activities of plant (Barker & Bryson, 2007; Hawkesford et al., 2012). Plant uptake nitrogen as nitrate (NO^{3-}) and ammonium (NH^{4+}) form. Compared to ammonium, nitrate is more soluble in soil, making it more accessible to plants and more prone to leaching. (Rennenberg et al., 2009; Miller & Cramer, 2004).

When plants lack nitrogen, their growth is usually inhibited and their leaves become narrow. Chlorosis brought on by N shortage typically begins in the older leaves and spreads to the younger leaves when N is remobilized. In the field, crops lacking nitrogen appear pale green or even yellow (Hawkesford et al., 2012). When tea plants lack nitrogen in the field, their internodes shorten and their young flushes have a lighter green hue than usual. Lower mature leaves may remain dark green and gradually become yellow as the deficit progresses, whereas younger leaves may turn yellow. The deficiency symptoms of nitrogen are presented in figure 2 which was found in Mehedibagh Division of Ghazipore Tea Estate which is located at Kulaura upazila of Moulvibazar district. A lack of nitrogen may result from feeder roots' reduced capacity to absorb nitrogen from the soil during dry spells and cold weather (TRFK, 2002; Hajiboland, 2017).

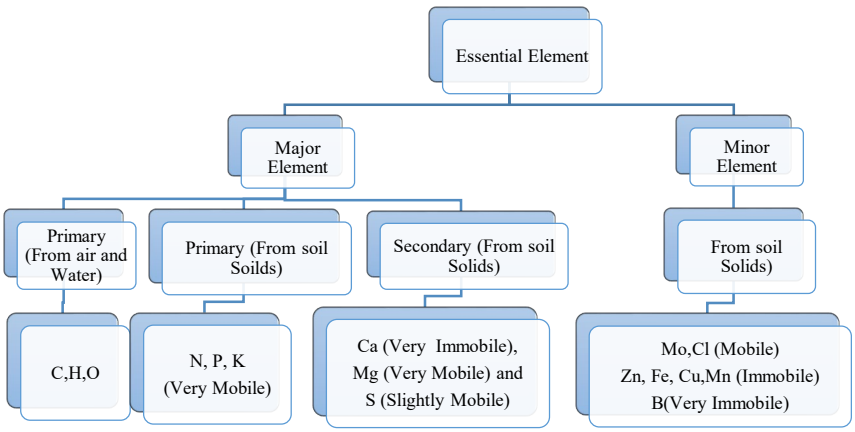


Figure 1. Types of essential elements

Figure 2. Nitrogen deficiency symptoms in tea plants

Figure 3. Phosphorus deficiency symptoms in tea plants

Figure 4. Potassium deficiency symptoms in tea plants

Sana (1989) also stated that, nitrogen deficiency may be somewhat seasonal especially due to waterlogged condition or obstruction by hardpan of soil. In Bangladesh the supply of nitrogen for tea soil through urea is very common phenomena and it's done in two splits depends on yield of the sections of a tea garden. For the favorable yields ranging from 1000 kg/ha to 3000 kg/ha 'made tea' per year the supplement of N by broadcasting method ranging from 110 kg/ha to 348 kg/ha Urea in a year as first split and 132 kg/ha Urea as second split (Kibria & Rashid,1994). Depending on the conditions of a tea field such as deficiency or boost up the yield or to recovery the yield after severe attack of helopeltis, nitrogen may be applied by foliar application (Urea 2 to 4 kg (1 to 2%) each in 200 liter water/ha) and two such application may be given at monthly interval especially September/October or October/November (Motalib & Dutta, 2011).

Phosphorous (P)

Additionally a necessary macronutrient, phosphorus is vital to higher plants' cellular composition and energy metabolism (Hawkesford et al., 2012). Phosphate ion concentrations in soil solutions can be as low as 0.001 (ppm), with in-plant dry weights ranging from 0.1% to 0.5%. Soil P is most accessible for plant growth in the soil pH range of 6.0 to 7.0 (Sharma et al., 2022). In the tea plant, phosphorus is essential for the growth of new wood and roots. Phosphorous encourages root growth of tea plants & cell division as well as being a constituent of ATP and ADP it involves in enzymatic reaction in tea plant cell (Kibria & Rashid, 1994). Khan et al. (2013) found that the critical limit for accessible phosphorus in tea soil is 10 $mgkg^{-1}$. A lack of brightness in tea, particularly in mature leaves, and dieback of both young and old woody stems are indications of phosphorus deficiency (TRFK, 2002). Motalib & Dutta (2011) stated that deficiency symptoms of phosphorous in tea plants are slowing down of the growth, late maturity, dark or grayish young leaves, stems become slender and often woody. The most visible deficiency symptoms of phosphorous in tea plants are smaller leaf and thinner branches. The most important deficiency symptoms of phosphorous in tea plant are dark green color and loss in glossiness of leaf (Kibria & Rashid, 1994; Motalib & Dutta, 2011). Figure 3 depicts phosphorus deficiency symptoms, which are most commonly reported at Bilascherra Experimental Farm in Srimangal and Monipur Tea Estate in Sylhet. Plant vitality is diminished due to a lack of protein production and fewer new rootlets (undeveloped roots). Based on tea output (1000 Kg/ha to 3000 Kg/ha), TSP fertilizer is applied at 44 Kg/ha to 88 kg/ha in tea fields using the broadcasting method during the first fertilizer split. If phosphorous deficiency found in the tea field, DAP fertilizer can be applied at 2% (4kg in 200 liter water/ha.) and two-three such application may be given at month interval (Kibria & Rashid, 1994; Motalib & Dutta, 2011).

Potassium (K)

Potassium is also vital in plant metabolic activities, where enough levels are required for numerous enzymatic reactions such as ATP and ADP (Sharma, 2022). The main source of K for tea plants are organic matter, minerals and chemical fertilizers. Potassium availability is influenced by a variety of parameters, including soil texture, pH, soil depth, and liming material, which explains why K uptake is frequently equal to or greater than nitrogen uptake. The essential limit of accessible potassium in tea soil, according to Khan et al. (2013), is 80 $mgkg^{-1}$. The deficiency symptoms of potassium are resulting in a lack of carbohydrate and hence poor foliage, development of thinner and twiggy wood with poor recovery after plucking and pruning. The most common and visible symptoms are scorching, Marginal necrosis in mature leaves and die-back (Motalib & Dutta, 2011). Figure 4 depicts the potassium deficiency symptoms identified at the Bangladesh Tea Research Institute (BTRI) Farm in Srimangal. Based on the yield of tea, MOP fertilizer is applied at 60 kg/ha to 150 kg/ha in tea field by broadcasting method during first split and 60 kg/ha during second split of fertilizer application to resolved the lacking of potassium (Kibria & Rashid, 1994). . If potassium deficiency found in the tea field, foliar application of MOP fertilizer can be performed at 1% (2kg in 200 liter water/ha.) (Motalib & Dutta, 2011).

Calcium (Ca)

Calcium is a major element and the sources of calcium are organic matter, minerals, and chemical fertilizers and lime (Zohora et al., 2022; Motalib & Dutta, 2011). In higher plants, calcium has a variety of specific roles, including impacts on enzymes, cell walls, and membranes. (Hawkesford et al., 2012). Calcium is necessary for continued growth of apical meristematic cells as well as most important for nitrate reduction in plant tissue (Motalib

& Dutta, 2011). The essential limit of accessible calcium in tea soil, according to Khan et al. (2013), is 90 $mgkg^{-1}$. Similar to potassium concentrations, calcium concentrations in plants range from 1 mgg^{-1} to 50 mgg^{-1} Ca dry matter, with different plant species having different essential calcium concentrations (Pilbeam & Morley, 2007). Plants that are inherently deficient in calcium have a range of diseases that impact their tissues or organs, even while the soil contains an excess of calcium. These diseases are characterized by a broad breakdown of membrane and cell wall integrity brought on by a deficiency of calcium in the tissues, which permits phenolic precursors to enter the cytoplasm. Furthermore, melanin compounds and necrosis are produced by the oxidation of polyphenols inside the impacted tissues. The disintegration of cell walls and membranes frequently results in microbial infection. (Pilbeam & Morley, 2007). In addition the most common and visible deficiency symptoms of Ca in tea plants are tips of plant and tips of top leaves die back, petiole & apical bud collapse with smaller inter-node and terminal bud usually dies. Break down at top and margin at tip (Kibria & Rashid, 1994). The deficiency symptoms of calcium are found in the Ghazipore Tea Estate's Mehdibagh Division in Kulaura, as seen in Figure 5. The shortage of Ca in tea soil can be resolved by applying dolomite depends on soil pH. Aluminium (Al^{3+}) toxicity can be decreased by applying lime or dolomite, which can replace Al^{3+} and H^{+} ions in the root plasma membrane with Ca^{2+} ions (Pilbeam & Morley, 2007).

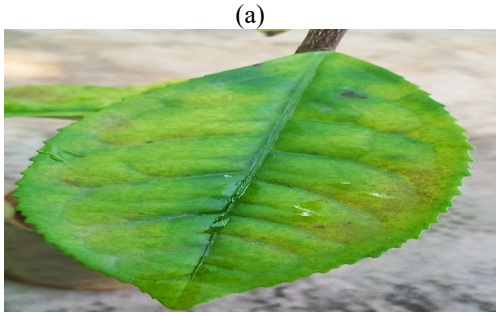
Magnesium (Mg)

As the only mineral component of the chlorophyll molecule that controls photosynthesis and is essential for the successful production of tea, magnesium is the most important nutrient for tea plants (Jayaganesh & Venkatesan, 2010). Furthermore, magnesium activates a wide range of enzymes involved in the metabolism of carbohydrates, nucleic acid production, and sugar translocation. (Kibria & Rashid, 1994). However, the majority of Bangladesh's tea-growing soils have low to medium levels of magnesium availability. The essential limit of accessible magnesium in tea soil, according to Khan et al. (2013), is 25 $mgkg^{-1}$.

On a dry weight basis, harvestable tea shoots have a magnesium content of 0.20% to 0.30%. Since tea is a leaf crop, it needs to be fertilized at high rates in order to yield large amounts of leaves. But each year, high K applications decrease Mg uptake because of the antagonistic relationship between K and Mg, which causes Mg deficiencies in tea plants (Venkatesan, 2006). Mature tea leaves exhibit the earliest signs of a magnesium deficit, which manifest as an inverted "V"-shaped chlorosis and yellow zones on either side of the older leaves' main veins. Eventually, the insufficiency causes the mature leaves to shed (Leaf shading is common and more severe in older leaves) and Necrosis is also common (Palani, 2019). The deficiency symptoms of magnesium are presented in Figure 6 (a, b) were found in a tea estate at Fatikchhari upazila of Chattogram district and Bilashcherra Experimental Farm, Srimangal. If magnesium deficiency found in the tea field, two times foliar application of 1% to 2% Magnesium Sulphate (2kg to 4 kg in 200 liter water/ha) can be performed at month interval (Motalib & Dutta, 2011).

Figure 5. Calcium deficiency symptoms in tea plants

(a)



(b)

Figure 6 (a, b). Mg deficiency symptoms in tea plants

Sulphur (S)

In addition to being nutrition, sulfur acts as a fungicide on tea plants. Sulphur-based compounds in various formulations were shown to be highly beneficial in preventing tea mite pests. As a result, in integrated nutrition and pest management strategies for tea cultivation, sulfur fertilizers have been suggested (Ahmed et al., 2011). Though, there is a various sources of sulphur unlike soil such as organic matter and manure, minerals, chemical fertilizers, although in some circumstances, there are some lacking of sulphur observed in tea plants (Motalib & Dutta 2011). Sulphur has some distinct function in tea plant. It is necessary for formation of certain

proteins and for cell division and plays a unique role in plant metabolism as well as assists the plant in the production of chlorophyll and increase root systems. It helps in proteins synthesis and chlorophyll formation (Gunaratne et al., 2008).

A sulfur deficit is characterized by a widespread yellowing of the leaves and a loss in leaf size; younger leaves are usually affected before older ones. Motalib & Dutta (2011) stated the yellowing of young leaves of tea in the early stage of sulphur deficiency, with severe deficiency even the older leaves become pale green or bright yellow and may cause tea- yellows. The veins of the tea leaves become lighter green than the rest of the leaves with narrow leaves due to sulphur deficiency. Figure 7 displays the symptoms of sulfur deficiency that were discovered at the Bangladesh Tea Research Institute (BTRI) plantation in Srimangal. If the deficiency is not addressed over an extended length of time, the yellowed leaves will eventually develop necrosis at the tips and margins, followed by defoliation. Foliar application of 1% Zinc Sulphate 1% to 2% Magnesium Sulphate can correct a sulfur deficiency (Motalib & Dutta 2011).

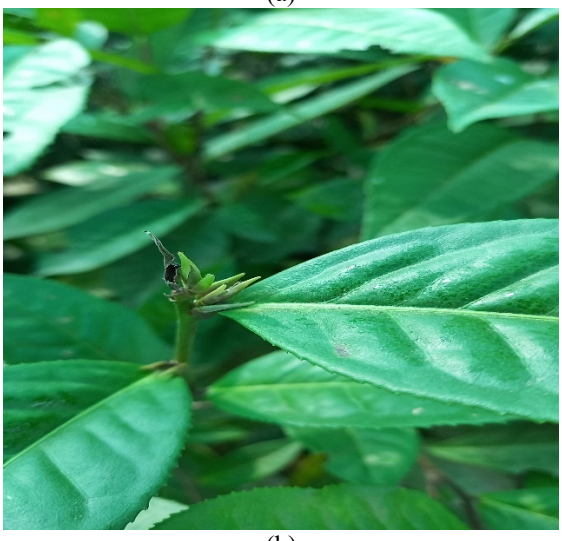
Figure 7. Sulphur deficiency symptoms in tea plants

Minor Element

Zinc (Zn)

The metabolic functions of zinc are the formation of growth hormones, promotes protein synthesis and enhance seed maturation and production. Severe zinc deficiency causes a significant death rate in tea plants as well as restricted growth; immature leaves become narrow, upright, distort, and curl apical buds, forming a rosette at the tip of the stem with sickle leaves that are unevenly sized and formed (Kibria & Rashid, 1994; Nelson, 2006; Motalib & Dutta, 2011). Figure 8(b) shows the zinc deficiency symptoms that were discovered in Sabari Tea Estate, and Bilashcherra Experimental Farm in srimangal. Since zinc is not readily absorbed by tea plants, foliar spray is the most efficient way to address a zinc deficiency; soil application is not recommended. Zinc application raises the yield of produced tea by increasing the amount of chlorophyll, the net photosynthesis rate, and the efficiency of water consumption (Hajiboland, 2017). During severity of zinc deficiency in the tea plants, foliar application of 1% Zinc Sulphate is the most effective way to correct the deficiency (Motalib & Dutta, 2011).

(a)



(b)

Figure 8 (a, b). Zinc deficiency symptoms in tea plants (Figure a is adapted from Nelson, 2006 and figure b was found in Bilashcherra Experimental Fam)

Boron (B)

Boron has a vital part in cell division, protein synthesis, nitrogen and carbohydrate metabolism, root system growth, reduces the rate of water absorption and sugar transfer, and is responsible for apical failure when inadequate (Zoysa, 2008; Kibria & Rashid, 1994). The supply of boron from soil to tea plants is quite low, making it one of the elements in tea plants that are the most immobile (McCauley et al., 2009). With the aging of tea, it was discovered that the amount of boron in the soil decreased (Hajiboland, 2018). In tea plant boron deficient create formation of cork mound on the leaf stalk (Muraleedharan et al., 2007), tip burning, and die back from the top is the most visible deficiency symptoms of boron deficiency. The deficiency symptoms of boron are presented in Figure 9. In addition leaves may become narrow, twisted, leathery and dark green in color due to boron deficiency in tea soil (Motalib & Dutta, 2011). If boron deficit occurs in the tea field, two foliar applications of 1% boron fertilizer at monthly intervals may be administered.

Figure 9. Boron deficiency symptoms in tea plants (adapted from Zoysa, 2008)

Copper (Cu)

Copper, a redox-active transition element, plays a role in respiration, carbon and nitrogen metabolism, photosynthesis (the production of chlorophyll), and oxidative stress resistance. Enzymatically bound copper, which catalyzes redox processes and aids in the metabolism of proteins and carbohydrates, accounts for the majority of the functions of copper as a nutrient for plants (Motalib & Dutta, 2011). The authors also revealed that copper nutritional status is likely to have a significant impact on the quality of green and black tea, as it increases fermentation duration.

The copper deficiency in tea plants are very distinct as slightly darker leaves with becoming dark brown rather than bright orange, weepy buds and plants are more prone to fungal diseases. Figure 10 depicts the copper deficiency symptoms discovered at Marina Tea Estate, Kulaura, Bangladesh Tea Research Institute (BTRI) Farm, Srimangal and Oodaleah Tea Estate, Chittagong. In Bangladesh, copper fungicides are used in tea gardens immediately after pruning to protect tea plants from fungal infection, which may play a significant role in correcting copper deficiencies in tea plants. (Motalib & Dutta, 2011).

Manganese (Mn)

Manganese has taken part as a constituent of chlorophyll and assimilated CO_2 during photosynthesis and breakdown carbohydrate. It has also various functions in enzymatic reactions, phosphorous translocation in tea plants as well as takes part in nitrogen and inorganic acid metabolism and helps in the formation of carotenes, riboflavin and ascorbic acid (Kibria & Rashid, 1994; Motalib & Dutta, 2011).

Manganese shortage is common in soils generated from manganese-poor parent material, as well as in extensively leached tropical soils. On the other hand, the amount of exchangeable manganese (mostly Mn^{2+}) in the soil solution was growing in acidic soils. One important strategy for reducing soluble manganese in acidic soils is the application of lime or dolomite (Hajiboland, 2018). The most visible Manganese deficiencies are marginal and interveinal chlorosis in mature and lower leaves, chlorotic and necrotic spots interveinal region of leaves with molted of red brown spots (Grey Speck disease) as well as number of green veins reduced (Kibria & Rashid, 1994; Motalib & Dutta, 2011). The manganese deficiency symptoms shown in Figure 11 were discovered at the Monipur Tea Estate in Sylhet; Ghazipore Tea Estate in Kulaura; and Bilashcherra Experimental Farm in Srimangal. During the survey manganese deficiency was found in the secondary nursery plants which age was above 1.5 years which might be due to low manganese content in the soil. Manganese deficiency can be corrected by the 1 to 2 time's foliar application of 1% manganese sulphate at monthly interval (Motalib & Dutta, 2011).

Chemical Analysis of Tea Leaf

The chemical analysis results of the collected tea leaf samples from different tea estates are given in the table 1 (Average values are used).

The leaf samples of the Mazdehee tea estate had the highest mean nitrogen content (5.18%), whereas the leaf samples of the Monipur tea estate had the lowest mean nitrogen content (2.95%) (Table 1). Significant variations ($^{ANOVA}F = 40.24$, $p < 0.001$) were observed in the content of nitrogen in tea leaf samples among the different tea estates (Figure 12). The tea leaf samples of Mazdehee tea estate had wider variability in their nitrogen contents (Figure 12). It was discovered that the average nitrogen content of the tea leaves in the Mazdehee tea plantation differed considerably from that of other tea gardens. In the tea leaf samples from Saif, Monipur, and Marina tea estates, there was no discernible variation in the mean nitrogen level (Figure 12). According to Owuor (1997), a tea plant is nitrogen deficient if its total leaf nitrogen concentration is less than 3%, slightly deficient if it is between 3.0% to 3.5% and sufficient condition if it is greater than 3.5%. As a result of the analysis of the gathered samples, it was discovered that tea leaf samples from the Monipur and Marina tea estates were nitrogen deficient, and the nitrogen content of the tea leaves from the Saif tea estate was slightly deficient. The nitrogen concentration of the tea leaves from Mazdehee tea estate was found to be sufficient.

Figure 10. Copper deficiency symptoms in tea plants

(a)

(b)

Figure 11 (a, b). Manganese deficiency symptoms in tea plants

Table 1. Chemical analysis of the tea leaves

Name of the Tea Estates	Total N (%)	Total P (%)	Total K (%)	Total Ca (%)	Total Mg (%)	Total Zn (%)
Marina	$2.97^{b} \pm 0.03$	$0.43^{a} \pm 0.05$	$1.72^{a} \pm 0.18$	$0.18^{b} \pm 0.03$	0.08 ± 0.008	0.003 ± 0.001
Mazdehee	$5.18^{a} \pm 0.88$	$0.28^{b} \pm 0.07$	$0.56^{b} \pm 0.15$	$0.49^{a} \pm 0.23$	0.08 ± 0.02	0.002 ± 0.001
Monipur	$2.95^{b} \pm 0.17$	$0.44^{a} \pm 0.06$	$1.88^{a} \pm 0.13$	$0.17^{b} \pm 0.03$	0.08 ± 0.01	0.004 ± 0.001
Saif	$3.07^{b} \pm 0.14$	$0.49^{a} \pm 0.06$	$1.68^{a} \pm 0.28$	$0.12^{b} \pm 0.06$	0.07 ± 0.007	0.003 ± 0.002

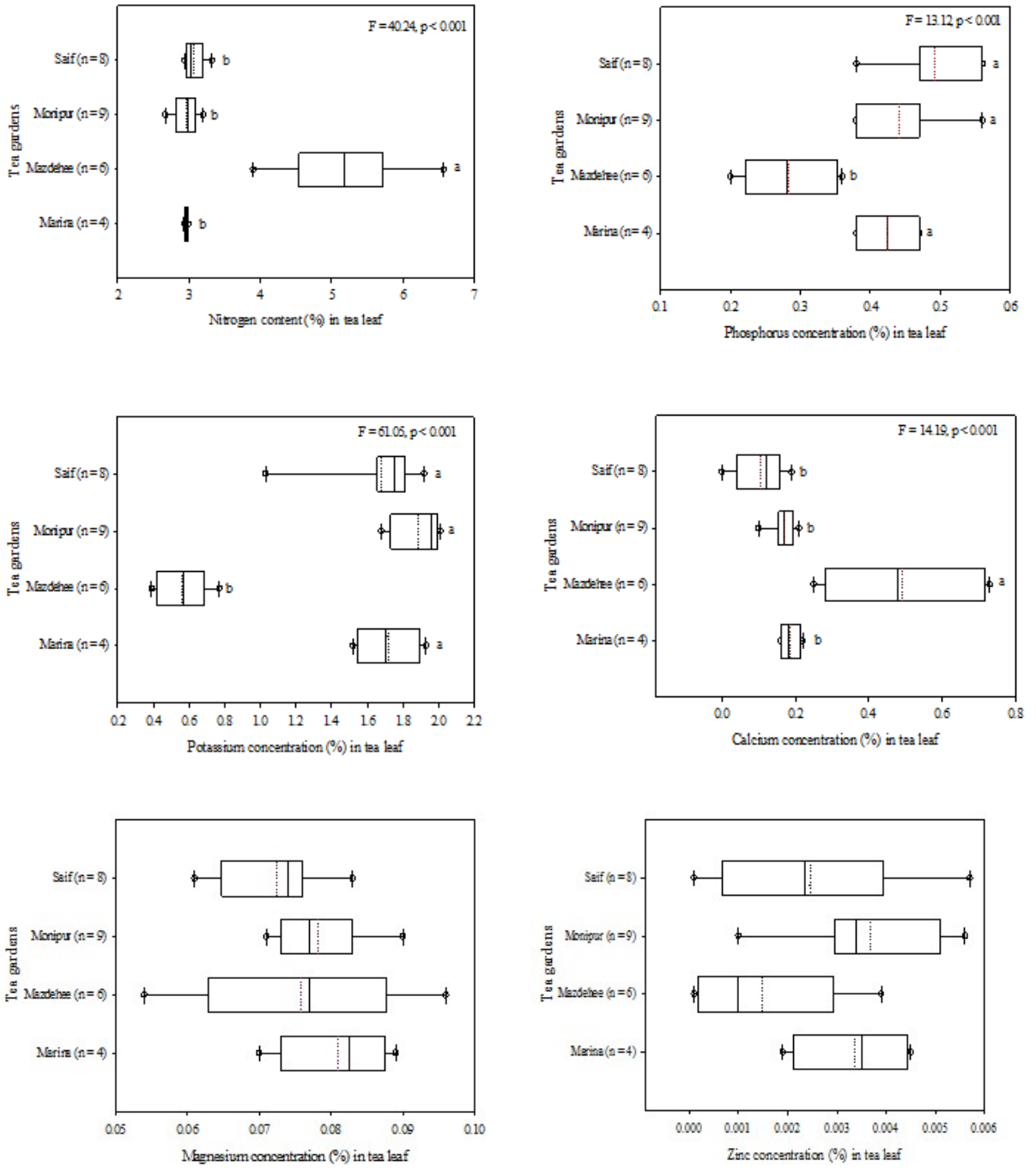


Figure 12: The nitrogen, phosphorus, potassium, calcium, magnesium, and zinc concentrations (%) in the tea leaves of various tea gardens are displayed in box and whisker plots.

Sample numbers are indicated by figures in parenthesis. The box plots display the median (solid line), the lower and upper quartiles (box), the 5th and 95th percentiles (circles), and the 10th and 90th percentiles (whiskers). An analysis of variance (ANOVA) test yielded the F-value and P-value. The F-value and P-value stand for the F-ratio, which shows how much variance there is among the tea gardens and how significant that variation is, respectively. The grouping for the tea gardens obtained using one-way ANOVA to distinguish pair-wise the mean of each tea garden is indicated by the Tukey letters a, b. There aren't many notable differences between the tea estates that have the same letters.

The highest mean content of Phosphorous (0.49%) was discovered in the leaf samples of Saif tea estate and the lowest mean content of phosphorous (0.28%) was found in the leaf samples of Mazdehee tea estate (Table 1). Significant variations ($^{ANOVA}F = 13.12$, $p < 0.001$) were observed in the content of phosphorous in tea leaf samples among the different tea estates (Figure 12). The tea leaf samples of Saif tea estate had wider variability in their phosphorous contents (Figure 12).

Compared to other tea gardens, the mean phosphorus content of the tea leaves of the Mazdehee tea estate was found to be significantly different. The mean amount of phosphorus in the tea leaf samples from the Saif, Monipur, and Marina tea estates was not significantly different (Figure 12). Same result was shown by Chen & Lin (2016) where phosphorus contents in tea leaves are 0.25% to 0.4%. During this research phosphorous deficiency of collected tea leaves were not found. Regarding this issue Hamid (2006) stated that under moderate soil pH conditions, roughly 5.5 to 7.0, tea plants have a good Phosphorous availability; however, Phosphorous availability may be reduced at pH values below 5.5 or over 7.0. Phosphorous is adsorbed onto the hydroxides of Fe and Al in extremely acidic soils, rendering it inaccessible to plants. The formation of roots is necessary for P absorption since the phosphate ion is immobile (Neumann & Römheld, 2012). Therefore, the analytical results of the collected leaf samples represent sufficiently supplement of phosphorous in tea leaf.

The leaf samples from the Monipur tea estate had the highest mean potassium content (1.88%), whereas the leaf samples from the Mazdehee tea estate had the lowest mean potassium content (0.56%) (Table 1). Significant variations ($^{ANOVA}F = 61.05$, $p < 0.001$) were observed in the content of potassium in tea leaf samples among the different tea estates (Figure 12). The tea leaf samples of Saif tea estate had wider variability in their potassium contents (Figure 12). Compared to other tea gardens, the mean potassium content of the tea leaves of the Mazdehee tea estate was found to be significantly different. In the tea leaf samples from Saif, Monipur, and Marina tea estates, there was no discernible variation in the average potassium level (Figure 12), however the tea leaves from Mazdehee tea estate showed a deficiency in potassium. The potassium levels of tea leaves were found to be 1.5% to 2.1% and 1.46% to 2.68% respectively, in similar types of studies (Chen & Lin, 2016; Adiloğlu & Adiloğlu, 2006).

The highest mean content of Calcium (0.49 %) was discovered in the leaf samples of the tea estate Mazdehee and the lowest mean content of Calcium (0.12 %) was found in the leaf samples of Saif tea estate (Table 1). Significant variations ($^{ANOVA}F = 14.19$, $p < 0.001$) were observed in the content of Calcium in tea leaf samples among the different tea estates (Figure 12). The tea leaf samples of all estate had smaller variability in their calcium contents (Figure 12). The mean calcium content of tea leaves from the Mazdehee tea plantation differed significantly from that of other tea gardens. The mean potassium level in tea leaf samples from the Saif, Monipur, and Marina tea estates did not differ significantly (Figure 12). Carr et al. (2003) estimated that among essential elements, young tea leaves contain on average 3560 $mgkg^{-1}$ (0.36%) Ca while old leaves contain on average 18,700 $mgkg^{-1}$ (1.87%) calcium. Adiloğlu & Adiloğlu (2006) found in another study that the calcium content of tea leaf samples ranged from 0.33% to 0.86%. It may be inferred from Table 01 and the results of the aforementioned studies that the leaf samples from the Marina, Monipur, and Saif tea estates are calcium deficient.

The highest mean content of Magnesium (0.08%) was found in the leaf samples of Mazdehee, Marina and Monipur tea estate and the lowest mean content of Magnesium (0.07%) was found in the leaf samples of Saif tea estate (Table 1). No discernible variations were found in the magnesium concentration of tea leaf samples from the various tea plantations (Figure 12). The tea leaf samples of Mazdehee, Monipur and Saif tea estate had wider variability in their Magnesium contents (Figure 12). According to the findings of Adiloğlu & Adiloğlu (2006) and Carr et al. (2003) where Mg content of tea leaves was 0.15% to 0.38% and 0.17% (young leaf) to 0.26% (old leaf) respectively; it can be evaluated that the Magnesium content of the collected leaf samples of these four tea estate (table.01) were deficient.

The leaf samples from the Monipur tea estate had the greatest mean zinc content (0.004%), whereas the leaf samples from the Mazdehee tea estate had the lowest mean zinc content (0.002%) (Table 1). There are no discernible variations in the zinc concentration of tea leaf samples between the various tea estates (Figure 12). The zinc contents of the tea leaf samples from the Mazdehee, Monipur, and Saif tea estates varied more widely (Figure 12). According to Özyazıcı et al. (2011) Zn contents of leaf samples were determined as 5.6 $mgkg^{-1}$ to 46.3 $mgkg^{-1}$ (0.0006% to 0.005%) and same research was done by by Adiloğlu & Adiloğlu (2006) where Zn content was 30 $mgkg^{-1}$ to 56 $mgkg^{-1}$ (0.003% to 0.006%). On the basis of the above findings our results of Zn content were determined sufficient (0.002% to 0.004%). Tea plants thrive in acidic soil, resulting in high Zn solubility (Adiloğlu & Adiloğlu 2006). As a result, zinc deficiency is rare in Bangladeshi tea plantations.

Conclusion

Tea is a monoculture crop that requires particular soil and environmental circumstances for optimal cultivation, such as heavy rainfall, high humidity, and acidic soil. Large volumes of fertilizer are required to obtain a high tea yield in tea-growing countries like Bangladesh due to global environmental changes like lower rainfall and/or inadequate distribution throughout the year. But when soil faces the lack of a specific nutritional component then it shows their deficiency symptoms in the plants. In essence, nutrient shortages lead to a decline in crop health and productivity and can also cause odd visual symptoms to manifest. By comprehending the function and mobility of each vital nutrient in the plant, one can determine which nutrient is accountable for a deficient symptom. Growth retardation, chlorosis, interveinal chlorosis, purple or red discoloration, and necrosis are examples of general deficiency signs. Older, lower leaves are the first to show signs of mobile nutrient shortages, while younger, upper leaves will show signs of static nutrient deficiencies. In order to confirm nutrient stress, soil or plant testing is

necessary. Mostly, visual observation serves as a diagnostic tool, but it might be limited by a number of factors, such as hidden hunger and false deficiencies. Based on the results of this survey study tea fresh leaf samples are analyzed where Nitrogen, Potassium, Calcium and Magnesium deficiency was determined which was correlated with collected photographs of deficiency symptoms in tea plants. However, assessing visual deficiency symptoms in the field is a quick and low-cost way to find possible nutrient deficiencies in tea plants. It is important to learn how to recognize symptoms and their causes in order to manage and solve issues with soil fertility and crop production, so this skill should be used effectively.

Declarations

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Performance of Bell Pepper (*Capsicum annum*) Under Different Grow Bag Media in Lalitpur District, Nepal

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ABSTRACT

Promoting rooftop farming using suitable grow bag media is of utmost importance in densely populated cities like Lalitpur to sustain the human race. To assess the productivity and other economic characteristics of bell peppers, an experiment was conducted from Feb 2022 to Jun 2022 in different grow bag media on the premises of Vegetable Crop Development Centre, Khumaltar, Lalitpur. The experiment was conducted in Randomized Complete Block Design (RCBD), with four replications and five treatments with growing media: Coco peat: vermicompost (1:1), Soil: sand: FYM (Farmyard Manure) (1:1:1), Soil: Sand: FYM: Vermicompost (1.25:0.75:0.5:0.5), Soil: vermicompost (1:1), and Soil: ash: FYM (1:0.5:1) on the cultivar California Wonder. Growth parameters like plant height (47.865 cm), number of leaves (50.6), number of branches/plant (9.5), and stem diameter, and yield parameters like total fruit weight (1693.93 gm), average fruit weight (84.68 gm), number of fruits (42.75), fruit diameter (6.37 cm), and fruit length (7.22 cm) were observed during the experiment. The media consisting of T3 (Soil: Sand: FYM: Vermicompost (1.25:0.75:0.5:0.5)) proved to be statistically superior over the rest of the combinations for almost all aspects under investigation, whereas comparatively poor performance was observed in Coco peat: vermicompost (1:1) media. This study suggests that the grow bag media of Soil: Sand: FYM: vermicompost (1.25:0.75:0.5:0.5) gave the highest gross return and net return, with the highest B: C ratio (2.08) observed in the grow bag media of Soil: Sand: FYM (1:1:1).

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Introduction

Bell pepper, also known as sweet pepper/capsicum, is a fruit of a solanaceous plant Capsicum annum, and is native to Central America and northern South America (Bosland, 1996). Different cultivars of this crop have different colors ranging from yellow, orange, and green to red and purple (Howard et al., 2000). Bell pepper shares the same genera with hot chili peppers (Capsicum fluorescence) which are used as condiments due to their pungency; however, it is not pungent because of the absence of pungent chemical capsaicin and is often called a sweet pepper (Govindarajan, 1986). Bell pepper is used as a green vegetable which is a rich source of vitamin C and other important micronutrients needed for the human body (Marin et al., 2004). Bell pepper is a plant of a relatively short cropping period, and high nutrient and antioxidant content (Navarro et al., 2006). It is very popular among commercial vegetable-growing farmers because of its high demand, relatively higher price, and low-price fluctuations over the year (Boriss & Brunke, 2005).

In Nepal, capsicum is cultivated in a 1470 ha area with a production of 15301 tons and a productivity of 10.41 tons/ha (MoALD, 2020Lalitpur, being one of the districts of Kathmandu Valley, is the most densely populated area in Nepal, covering an area of 385 sq. km and a head population of 548,401. (CBS Annual Report, 2019). In Lalitpur, Capsicum is cultivated in an area of 62 ha with a production of 1190 Mt and a yield of 19.25 Mt/ha which is higher than the National average (10.41 Mt/ha) (MoALD, 2020).

Lalitpur faces a high demand for vegetables, but limitations like land fragmentation, high population density, and conversion of productive land for commercial purposes restrict local production, forcing many households to buy vegetables at a premium. People are practising terrace farming with the use of locally available materials. In rooftop farming, the choice of different grow bag media for the cultivation of vegetables is situational and complicated. Urban farmers are facing uncertainty in

the selection of potting mixture and agricultural suppliers promoting expensive grow bag mediums. The potential growing media could be coco peat: vermicompost (1:1) (Brunda SN & Devi Singh, 2023). Very few research studies were carried out in Nepal to evaluate the growth and yield parameters of bell peppers by using different growing media. Therefore, this study aimed to evaluate using locally available and inexpensive media for cost-effective and organic bell pepper production. This experiment will not only find out the productive and cost-effective combination of grow bag media but also pave the way for further studies.

Materials and Methods

Experimental Site

The experiment was conducted from February 2022 to June 2022 in the office premises of the Vegetable Development Centre, Khumaltar, Lalitpur. It is located in the south-central part of Kathmandu Valley at an altitude of 1,400 meters with 27° 32' 31.0812" N latitude and 85° 20' 3.4692" E longitude. This region has a sub-tropical climate with mild summer and cold winter (DHM, 2022).

Weather Conditions During the Experiment

Weekly interval average data on different weather parameters i.e., maximum and minimum temperatures, precipitation and relative humidity recorded during the potato growing season is presented in Figure 1.

Experimental Details

The experiment was laid out in Randomized Complete Block Design (RCBD) with four replications and 5 treatments. Each plot had 5 grow bags, and, in each grow bag, a single plant was transplanted. The size of the grow bag was 24cm* 24 cm*40 cm. California Wonder was the cultivar of bell peppers used in the experiment. It is a sturdy and wide-frame cultivar and is very suitable for rooftop gardening in growing bags. Treatment details are shown in the Table 1.

Crop Management Practices

Seedlings were grown in a tray containing Coco peat inside the greenhouses. After two weeks, seedlings were transferred into plastic bags containing coco peat and vermicompost (1:1). A solution of mancozeb (2%) was sprayed as a prophylactic measure to control fungus. They were transplanted on grow bags after 1 month. Grow bag mixes were prepared by mixing individual components of treatments in the ratio mentioned by volume. The grow bag filled 3/4 of its space. A basal dose of fertilizer i.e., 1 gram of urea, 1.25 gram of DAP and 1.25 gram of MOP was applied before transplanting. Another dose of 1 gram of urea was given at 50 DAT (Days After Transplanting) and 2% complete fertilizer at 35 DAT and 70 DAT were sprayed. The plants were sprayed with SAAF fungicide 2% by volume at 10-day intervals. We avoided using insecticide because there were no significant insect issues.

Observations

The height of the plant from ground level to the growing tip and the number of leaves were measured after 30 days of transplanting for the first time and after every 25-day interval. The number of branches capable of fruiting was measured at 55 and 85 days after transplanting. Stem diameters were measured at the final harvest stage at about 2cm from the ground level using vernier callipers from 5 sample plants and averages were calculated. Number of fruits per plot is calculated by adding all the number of fruits harvested throughout the research. The weight of a marketable fruit per plant was determined as the total weight of healthy fruit to the total no of sample plants at harvest which can be sold in the market. The fruits were harvested in 70, 77 and 84 days after transplanting. The yield components of the crop were recorded accordingly using an electronic balance. The benefit-cost analysis of different treatments was carried out by using the formula:

$$\frac{B}{C}\ \text{ratio} = \frac{\text{Gross Return}}{\text{Variable Cost}}$$

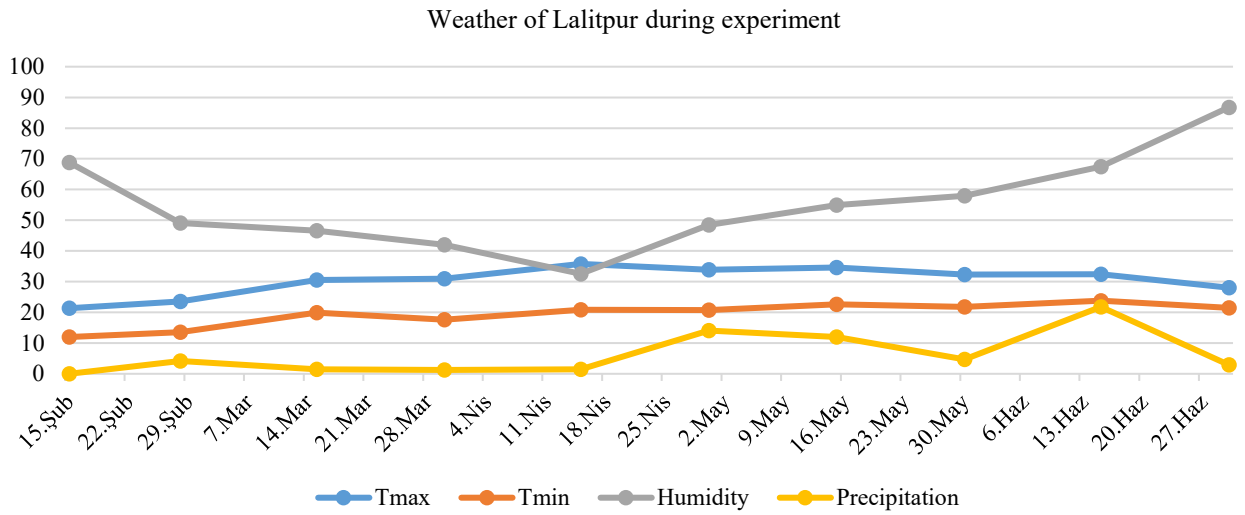

Figure 1. Weather conditions during the experiment in Lalitpur (NASA Powe, 2022). Temperatures in the figure are given in Celsius

Table 1. Treatment details

Treatment No.	Name of Treatment	Ratio	Symbol
1	Coco peat: Vermicompost	1:1	T1
2	Field soil: Sand: FYM	1:1:1	T2
3	Soil: Sand: FYM: Vermicompost	1.25:0.75:0.5:0.5	T3
4	Soil: Vermicompost	1:1	T4
5	Soil: Rice husk ash: FYM	1:0.5:1	T5

FYM: Farmyard Manure

Table 2. Effect of growing media on Plant height of bell peppers

Treatments		Plant height(cm)		
		30DAT	55DAT	80DAT
T_1	Coco peat: vermicompost (1:1)	12.14^{a}	21.65^{c}	37.1^{c}
T_2	Soil: sand: FYM (1:1:1)	11.63^{a}	27.5^{b}	43.2^{b}
T_3	Soil: sand: FYM: vermicompost (1.25:0.75:0.5:0.5)	12.30^{a}	31.4^{a}	47.87^{a}
T_4	Soil: vermicompost (1:1)	11.1^{a}	24^{c}	41.65^{b}
T_5	Soil: ash: FYM (1:0.5:1)	11.11^{a}	27.48^{b}	42.83^{b}
LSD (0.05)		1.55	2.92	3.93
C V%		8.62	7.19	11.14
Grand mean		11.65	26.41	42.53

Note: LSD, Least Significant Difference; SEm, Standard Error of mean; CV (%), Coefficient of Variation; DAT, days after transplanting. Means followed by the common letter(s) within each column are not significantly different at a 5% level of significance by the DMRT test.

Table 3. Effect of growing media on growth parameters of bell peppers

Treatments	Number of leaves			Number of branches		Stem diameter (cm)
	30 DAT	55 DAT	80 DAT	55DAT	80 DAT	80 DAT
T_1	7.25^{b}	19.54^{b}	37.4^{e}	5.85^{b}	6.5^{c}	1.05^{b}
T_2	10.45^{a}	35.15^{a}	47.35^{b}	6.4^{ab}	8.3^{b}	1.24^{a}
T_3	10.65^{a}	37^{a}	50.6^{a}	7.25^{a}	9.5^{a}	1.37^{a}
T_4	9.35^{a}	34.15^{ab}	42.35^{d}	6.8^{a}	7.8^{b}	1.19^{ab}
T_5	10.05^{a}	34.9^{a}	44.75^{c}	6.55^{ab}	8.35^{b}	1.26^{a}
LSD (0.05)	1.51	2.50	2.23	0.80	0.61	0.17
SE (+-)	0.21	0.36	0.32	0.11	0.09	0.024
C V%	10.23	7.92	9.02	7.92	4.86	9.02
Grand mean	9.55	32.15	44.49	6.57	8.09	1.23

Note: LSD, Least Significant Difference; SEm, Standard Error of mean; CV (%), Coefficient of Variation; DAT, days after transplanting. Means followed by the common letter(s) within each column are not significantly different at a 5% level of significance by the DMRT test.

Statistical Analysis

The data recorded on different parameters from the field and laboratory were first tabulated in Microsoft Excel (MS- Excel), and then Analysis of Variance (ANOVA) for all data was computed using the R-STUDIO computer software package. All the analyzed data were subjected to Duncan's Multiple Range Test (DMRT) for mean comparison at a 5% level of significance.

Results and Discussions

Effect of Growing Media on Growth Parameters of Bell Peppers

The use of different types of grow bag media showed a significant effect on the growth characteristics of bell peppers. Initially (30DAT), the performance of all the treatments was statistically similar. Later, significantly the highest plant height (47.865 cm) (Table 2), highest number of leaves (50.6) and the highest number of branches/ plants (9.5) were observed in T_3 (Soil: sand: FYM: vermicompost (1.25:0.75:0.5:0.5)) (Table 3). In most of the cases, the performance of plants in T_2, T_5 and T_4 was statistically similar, whereas T_1 showed the poorest performance on all dates. No significant difference was found in Stem diameter in all treatment combinations. The highest (1.37) and smallest (1.045 cm) stem diameter was recorded in the T_3 and T_1 respectively.

On average well-decomposed farmyard manure contains 0.5 percent N, 0.2 percent P_2O_5, and 0.5 percent K_2O (Shinde, 1992). Vermicomposting causes a considerable increase in available phosphorus, exchangeable potassium, calcium, and nitrogen (Nath, Singh, & Singh, 2009). Vermicompost contains high levels of readily available macro- and micronutrients, organic acids, and active microbial populations (Roy, Srivastava, Kumar, & Singh, 2010). Sand is an excellent medium for drainage and aeration since it warms and cools rapidly (Gungor & Yildirim, 2013). The maximum plant height observed in the treatment combination of Soil: sand: FYM: Vermicompost may have resulted from improved aeration, water retention, and nutrient availability in the growing media, which enhance plant vegetative growth, especially nitrogen and phosphorous, by promoting cell division and elongation (Gopinath et al., 2008). This result agrees with the findings of Kumar and Kohli (2005) in capsicum.

Coco peat has a very high water-holding capacity which causes poor aeration in the root zone (Hebbar, et al., 2011). Depending on the handling and processing technique, the physical properties of coco peat can easily affect the air

capacity and water retention. (Abad, Noguera, Puchades, Maquieira, & Noguera, 2002). The most suitable soil to grow capsicum is well-drained sandy loam soils with good percolation (Hebbar, et al., 2011). Waterlogging should not occur on the growing site because water stagnation harms the crop (Denzongpa & Sharma, 2013). Therefore, the poor performance of T_1 might be the water retention capacity of coco peat as waterlogging is detrimental to plants.

Effect of Growing Media on Yield Parameters of Bell Peppers

It is evident from Table 3 that the yield characteristics of bell peppers showed significant differences among different treatments of growing media. Total fruit weight per plot was recorded as the highest in the second harvest in all five treatments. In the second harvest, the highest total fruit weight was found in T_3, which was 1693.93gm and it was followed by T_4, T_2 and T_5 (Table 4). The lowest total fruit weight per plot of 891.36g was observed in the control treatment of Coco peat: vermicompost (1:1) (Table 4). Similar result was recorded in the first and third harvests. In the case of average fruit weight per plot, no significant difference was observed in all treatment combinations. The highest (84.68g) and the smallest (73.02g) average fruit weight per plot was recorded in the T_3 and T_1 respectively (Table 4). Similarly, the total number of fruits per plot was highest in T_3 (42.75) and T_5 showed the least number of fruits (26). Significant difference among the various treatment combinations was recorded in fruit diameter. T_3 (6.37 cm) showed superior performance, which was followed by T_2, T_4, T_5 and T_1. No significant difference was observed in fruit length in all treatment combinations. The highest fruit length was recorded in T_3 (7.22 cm) which was statistically similar to T_2, T_4, T_5 and T_1. This result agrees with the findings of Roy et.al, (2010) Llaven et al. (2008) and Uma Maheshwari and Haripriya (2007), where FYM and vermicompost-based growing media showed better yield traits.

Treatment containing sand and vermicompost might provide an ideal condition for the growth and development of capsicum fruit as sandy loam soil with better aeration is good for capsicum. Pepper plants thrive on more nitrogen than other crops, resulting in increased flower and fruit production (Haifa Group). When the soil lacks sufficient phosphorus, pepper plants will suffer stunted growth, with shorter and weaker branches, fewer flower buds forming, and ultimately, a decrease in overall fruit production (Haifa Group). A similar result was observed by Chewaka, Mohammed, & Kassa (2022), where potting media containing Compost + FYM + Topsoil showed superior performances.

Marketable and non-marketable Fruit Weight Per Plot

Different treatments had different effects on the marketable and non-marketable weight of fruits per plot. At the time of the second harvest, the highest marketable weight per plot (1615.25 g) was found in the grow bag containing Soil: Sand: FYM: vermicompost (T_3) and the lowest marketable weight per plot (809.45 g) was recorded in Coco peat and vermicompost (T_1) (Table 5). A similar trend was observed in the third harvest. The weight of non-marketable fruit per plot was highest (128.68g) in T_5, while it was found lowest (78.68 g) in T_3. However, the weight of non-marketable fruit per plot was highest (233.58g) in T_1 and the lowest in T_3 at the time of the third harvest.

Table 4. Effect of growing media on yield parameters of bell peppers

Trt	Total fruit weight per plot (g)			Average fruit weight (g)					
	1st hrv	2nd hrv	3rd hrv	1st hrv	2nd hrv	3rd hrv	FN	FD	FL
T_1	224.53^{d}	891.36^{c}	610.18^{b}	70.38^{c}	73.02^{c}	60.60^{b}	25.5^{d}	4.27^{d}	5.17^{c}
T_2	503.56^{b}	1350.07^{b}	882.43^{a}	77.29^{bc}	79.16^{abc}	69.52^{a}	36.25^{b}	6.07^{b}	6.48^{ab}
T_3	786.25^{a}	1693.92^{a}	991.78^{a}	85.23^{a}	84.68^{a}	73.63^{a}	42.75^{a}	6.37^{a}	7.22^{a}
T_4	530.56^{b}	1266.8^{b}	611.25^{b}	81.63^{ab}	80.22^{ab}	69.67^{a}	31^{bc}	6.015^{c}	6.28^{b}
T_5	343.9^{c}	985.22^{c}	572.56^{b}	72.13^{c}	74.03^{bc}	70.58^{a}	26^{d}	5.325^{d}	5.48^{bc}
LSD (0.05)	105.06	186.72	136.58	7.14	6.62	6.93	4.13	0.31	0.67
SE (+-)	15.24	27.09	19.82	1.04	0.96	1.01	0.599	0.60	0.43
CV%	14.27	9.79	12.08	6.00	5.49	6.54	8.30	8.30	7.68
Grand mean	477.8	1237.5	733.6	77.33	78.22	68.80	32.30	5.61	6.57

Note: LSD, Least Significant Difference; SEm, Standard Error of mean; CV (%), Coefficient of Variation; DAT, days after transplanting. Means followed by the common letter(s) within each column are not significantly different at a 5% level of significance by the DMRT test.

Table 5. Effect of growing media on marketable and non-marketable fruit weight of bell peppers.

Treatments	Second Harvest		Third Harvest	
	Marketable fruit weight per plot(g)	Non-marketable fruit weight per plot(g)	Marketable fruit weight per plot(g)	Non-marketable fruit weight per plot(g)
T_1	809.45^{d}	81.93^{c}	376.6^{e}	233.58^{a}
T_2	1257.35^{b}	92.73^{b}	673.4^{b}	209.03^{b}
T_3	1615.25^{a}	78.68^{d}	876.78^{a}	115^{d}
T_4	1178.63^{b}	88.18^{bc}	482.58^{c}	128.68^{d}
T_5	856.54^{d}	128.68^{a}	419.13^{d}	153.43^{c}
SE (+-)	1.45	0.96	1.24	0.89
CV%	11.2	14.09	9.5	10
Grand mean	1143.44	94.03	565.70	167.94

Note: LSD, Least Significant Difference; SEm, Standard Error of mean; CV (%), Coefficient of Variation; DAT, days after transplanting. Means followed by the common letter(s) within each column are not significantly different at a 5% level of significance by the DMRT test.

Table 6. Effect of different grow bag media on the performance of bell pepper: economic analysis

Treatments	Total cost of production (NRs/ plot)	Net return (NRs/ plot)	Gross return (NRs/ plot)	B: C ratio
Coco peat: vermicompost (1:1)	650.12	-71.12^{e}	579.00^{c}	0.89^{e}
Soil: sand: FYM (1:1:1)	368.23	398.07^{ab}	766.30^{b}	2.08^{a}
Soil: sand: FYM: vermicompost (1.25:0.75:0.5:0.5)	479.76	432.24^{a}	912.00^{a}	1.90^{ab}
Soil: vermicompost (1:1)	512.97	98.2^{c}	611.17^{bc}	1.19^{c}
Soil: ash: FYM (1:0.5:1)	415.12	36.11^{d}	451.23^{d}	1.08^{cd}
SE (+-)		0.97	1.23	0.65
C V%		8.43	9.34	7.65

Note: LSD, Least Significant Difference; SEm, Standard Error of mean; CV (%), Coefficient of Variation; DAT, days after transplanting. Means followed by the common letter(s) within each column are not significantly different at a 5% level of significance by the DMRT test

Economies of Bell Pepper Production Effective Tiller Per m^2

The use of different grow bag media had a profound effect on the cost of production, net return per plot, gross return per plot, and Benefit: Cost ratio. The total cost of production per plot was highest (650.12 rupees) in the control treatment of Coco peat: vermicompost (1:1) whereas it was found to be lowest (368.23 rupees) in the conventional potting mix i.e., Soil: sand: FYM (1:1:1) (Table 6). The gross return was highest (912 rupees) in the treatment with soil, sand, FYM, and vermicompost in the ratio of 1.25:0.75:0.5:0.5 whereas the gross return was found the lowest (451.23 rupees) in the treatment of Soil: ash: FYM (1:0.5:1) (Table 6). The benefit: cost ratio was highest (2.08) on the treatment containing soil, sand, and FYM on the ratio of 1:1:1 which was followed by Soil: sand: FYM: vermicompost (1.25:0.75:0.5:0.5). The B: C ratio was lowest and less than zero (0.89) on the mixture of cocopeat and vermicompost in the ratio of 1:1 (Table 6). It can be explained by the higher cost of both the raw materials.

Conclusions

The use of different grow bag media had a profound effect on growth, yield, and economic traits of the 'California Wonder' cultivar of bell pepper. The grow bag mix containing soil, sand, FYM and vermicompost in the ratio of 1.25:0.75:0.5:0.5 increased growth traits such as plant height, number of leaves and stem diameter; and yield attributing traits namely the number of branches, total fruit weight, average fruit weight and marketable fruit weight in capsicum. The gross return was the highest in the same treatment while net return and B: C were observed the highest in the treatment with the grow bag containing a mixture of soil: sand: FYM (1:1:1). Therefore, the use of the grow bag mix containing soil, sand, FYM and vermicompost in the ratio of 1.25:0.75:0.5:0.5 is beneficial to get the highest production bell pepper in Lalitpur district.

Declarations

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Current Situation and Economic Analysis of Beekeeping Activities in Kemaliye District of Erzincan Province

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ABSTRACT

Beekeeping represents a promising alternative source of employment and income for rural populations, offering unique opportunities. Despite Turkey's favourable ecological conditions for beekeeping, the sector's potential remains largely untapped. This study aimed to assess the current state of beekeeping activities in Kemaliye district of Erzincan province, a region of significant ecological importance, abundant areas suitable for bee breeding and rich plant diversity. In this context, the primary data for the study were collected through a comprehensive census of 87 beekeepers operating in the Kemaliye district of Erzincan province in 2023. In addition to the demographic characteristics of the beekeepers, detailed data were obtained on a number of other issues. These included economic analysis of beekeeping, non-beekeeping activities, bee products produced, honey yields, colony numbers, queen replacement and production, disease and pest control, travelling beekeeping status, feeding methods and times, colony losses, important problems encountered in beekeeping, marketing and sales activities. The results of the research indicate that the cost of 1 kg of honey in the Kemaliye district of Erzincan province was calculated as 141.89 TL for fixed beekeepers and 107.20 TL for nomadic beekeepers. The total cost per hive was 1409.75 TL for fixed beekeepers and 1007.83 TL for nomadic beekeepers.

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Erzincan İli Kemaliye İlçesinde Arıcılık Faaliyetlerinin Mevcut Durumu ve Ekonomik Analizi

MAKALE BİLGİSİ

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ÖZ

Arıcılık kendine has özellikleri ile kırsal nüfus için iyi bir alternatif iş ve gelir kaynağıdır. Türkiye ekolojik olarak arıcılığa çok uygun bir doğaya sahip olmasına rağmen maalesef potansiyelinin çok azını kullanmaktadır. Bu çalışma, ekolojik yapısı bakımından arı yetiştiriciliğine uygun alanların fazlalığı, zengin bitki çeşitliğine sahip olması nedeni ile önemli bir konuma sahip olan Erzincan İli Kemaliye ilçesindeki arıcılık faaliyetlerinin mevcut durumunu değerlendirmek amacıyla yürütülmüştür. Bu kapsamda 2023 yılında Erzincan ili Kemaliye ilçesinde faaliyet gösteren 87 arı yetiştiricisi ile tam sayım yapılarak çalışmanın birincil verileri toplanmıştır. Anket çalışmasında 26 soru ile arıcıların demografik özelliklerinin yanı sıra, arıcılığın ekonomik analizi, arıcılık dışı faaliyetleri, üretilen arı ürünleri, bal verimleri, koloni sayıları, ana arı değişimi ile üretimi, hastalık ile zararlılarla mücadeleleri, gezginci arıcılık durumları, besleme şekil ile zamanları, koloni kayıpları, arıcılıkta karşılaştıkları önemli sorunları, pazarlama ve satış faaliyetleri gibi konular hakkında ayrıntılı veriler elde edilmiştir. Araştırma sonuçlarına göre Erzincan ili Kemaliye ilçesinde 1 kg bal maliyeti sabit arıcılarda 141,89 TL, göçer arıcılarda ise 107,20 TL olarak hesaplanmıştır. Kovan başına toplam maliyet sabit arıcılarda 1409,75 TL, göçer arıcılarda ise 1007,83 TL olduğu tespit edilmiştir.

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Giriş

Arıcılık, Zar kanatlılar takımına ait Apoidea familyasındaki Apis cinsine ait türlerinden oluşan bal arısını, bitkisel kaynakları ve emeği kullanarak, insanın beslenmede ve sağlığını korumak amacıyla kullanmaktan vazgeçemediği bal, polen, arı sütü, propolis, arı zehri gibi ürünler ile günümüzde arıcılığın önemli gelir unsurlarından olan ana arı, oğul gibi canlı materyalleri üretme faaliyetidir (Fıratlı ve ark., 2000). Arıcılık faaliyeti yapısı gereği; kısa sürede gelir getirmekte, küçük sermaye ile ve ikinci ek iş olarak yapılabilmekte, mülkiyetli arazi varlığına bağlı bulunmamakta, yüksek ve engebeli yaylalarda yapılabilmektedir. Arıcılık, diğer tarımsal faaliyetlere kıyasla nispeten düşük emek yoğunluğuna rağmen, kırsal topluluklar için istihdam ve gelir fırsatlarının yanı sıra sağlıklı beslenme kaynağı da sunmaktadır (Uzundumlu ve ark., 2011).

Artan nüfusun beslenme ihtiyaçlarının karşılanması açısından Dünyada arıcılık faaliyetleri desteklenmekte ve önemli görülmektedir. 2021 yılında dünyada üretilen balın %30'u uluslararası ticarete konu olmuştur (TEPGE 2023).

Türkiye, tüm arı ürünleri arasında en çok talep gören bal üretimi için oldukça uygundur. Çeşitli bitki örtüsünün yıl boyunca çiçek açması da dahil olmak üzere üretimi destekleyen faktörlerin bir araya gelmesi, Türkiye'de arıcılığın belirleyici bir özelliği olarak görülebilir (Burucu ve Bal, 2017). Türkiye 8.984.676 adet toplam kovan sayısı ile 2022 yılında 118.297 ton bal üretimi gerçekleştirmiştir (TÜİK 2022). Türkiye Çin'den sonra en önemli ikinci bal üreticisi konumundadır (TEPGE 2021).

Bu araştırmaya konu olan Erzincan ili bal üretimi bakımından Türkiye'de 24. sırada yer almaktadır. Yaklaşık 116.943 adet koloni varlığına sahip olan Erzincan ilinde 2022 yılı bal üretimi 1.673 ton civarında olup koloni başına verim ise ortalama 14.31 kg'dır (TÜİK, 2022). Kemaliye İlçesi coğrafya olarak dağlık ve yüksek rakımlı yaylalara sahip, zengin bitki florasının yanında endemik türlere de sahip olan bir bölgedir. Bu çalışmanın amacı, kısıtlı tarım arazisine sahip olmasına karşın, alternatif tarımsal faaliyet olan arıcılık açısından uygun şartlara sahip olan Kemaliye ilçesindeki arıcılığın mevcut durumunu değerlendirmektir.

Materyal ve Yöntem

Materyal

Çalışma kapsamında birincil ve ikincil verilerden yararlanılmıştır. İkincil veriler, Türkiye İstatistik Kurumu (TÜİK) ve diğer istatistik kurumları, Tarım ve Orman Bakanlığı veri tabanları, konu ile ilgili yapılmış ulusal ve uluslararası literatürlerden yararlanılmıştır.

Çalışmanın temel materyalini birincil veriler oluşturmuştur. Birincil veriler ise, Kemaliye'de arıcılık faaliyeti yapan üreticiler ile çalışmanın amacına uygun bir şekilde hazırlanan anket formları ile yüz yüze anket gerçekleştirerek elde edilmiştir.

Bir popülasyon üzerinde yürütülen araştırmada popülasyona ait verilerin toplanmasında kullanılan iki yöntemden birisi tam sayım diğeri ise örneklemedir. Popülâsyonu oluşturan birimlerin tek tek incelenerek onlardan ölçme, tartma, gözlem veya soruşturma yoluyla bilgi alınmasına tam sayım adı verilmektedir (Güneş ve Arıkan, 1988). Araştırma yapılacak popülasyon küçük, istenilen bilgilere ulaşmak kolay ve ucuz ise tam sayım yapılmalıdır. Tam sayım sonucu elde edilen bilgiler eğer özenle derlenmiş ise daha doğru sonuçları yansıtır (Çiçek ve Erkan, 1996).

Araştırmanın popülasyonunu 2023 yılında, Erzincan İli Arı Yetiştiricileri Birliğine kayıtlı Kemaliye ilçesindeki 87 arıcı oluşturmaktadır. Bu arıcılarla tam sayım yöntemine göre çalışma yürütülmüştür.

Çalışmanın etik kurul kararı, 28.03.2024 tarihi ve 14 karar numarası ile Malatya Turgut Özal Üniversitesi, Sosyal ve Beşeri Bilimler Araştırmaları Etik Kurul Başkanlığı tarafından verilmiştir.

Yöntem

Araştırmada veri toplama aracı olarak, çoktan seçmeli ve açık uçlu sorulardan oluşan anket formu kullanılmıştır. Anket formunda, demografik özellikleri, arıcılıktaki amaçları, arıcılığa nasıl başlanıldığı, bal verimlerini, üretim çeşitliliği, sabit veya gezginci arıcılık durumu, arıcılığın ekonomik analizi, konaklama ve hasat bilgileri, alet-ekipman varlıkları, arı ırkı ve koloni bilgileri, besleme şekilleri, sorunlar ve pazarlama yapısı gibi bilgileri belirlemeye yönelik 26 soru yer almaktadır. Anketlerden elde edilen veriler ile betimsel analizler yapılmıştır.

Ekonomik Analizlerin Yapılmasında Kullanılan Yöntem: Ekonomik analizlerde üretim masrafları, sabit ve değişken masraflar olarak iki grupta incelenmiştir. Değişen masraflar olarak, arı besleme, pazarlama, nakliye, konaklama, arı bakım ve ilaç, temel petek, alet-tamir-bakım, geçici işçilik masrafları, döner sermaye faizi; sabit masraflar olarak ise genel idare giderleri, aile işgücü ücret karşılığı masrafları hesaplanmıştır. Ekonomik analiz olarak, işletme ve kovan başına ortalama üretim miktarları, 1 kg bal maliyeti, ortalama bal kg satış fiyatı, 1 kg bal net karı ve kovan başı ortalama masraf hesaplanmıştır.

Bulgular

Çalışmaya Katılanların Demografik Özellikleri

Araştırma bulgularına göre, arıcılık yapanların yaş durumları incelendiğinde ilk sırada %42,5'lik oranla 51-60 yaş aralığındaki grubun yer aldığı görülmüştür (Çizelge 1). Çalışmada göçer arıcıların yaş ortalaması 57,57 ve sabit arıcıların 59,44'dür. Arıcıların genelinde yaş ortalaması 58,64'tür ve 39 yaş altında arıcı olmadığı görülmüştür. Genç nüfusun arıcılık yapma konusunda fazla istekli olmadıkları, arıcılığın ek gelir ve emeklilikten sonra yapılan bir uğraş olarak daha çok benimsendiğinden çoğunlukla ileri yaşlarda yapılan bir faaliyet olduğu görülmektedir. Arı yetiştiriciliğinin daha cazip hale getirilmesi ve genç yaştaki kişilere arıcılığın özendirilmesinin gerektiği anlaşılmaktadır. Onuç ve ark. (2019) tarafından İzmir ili Kemalpaşa ilçesinde yapılan çalışmada yetiştiricilerin yaş ortalaması 47'dir. Parlakay, (2004) Tokat ili Merkez ilçesinde yapılan bir çalışmada yetiştiricilerin yaş ortalaması 49,3'tür. Saner ve arkadaşları (2011) tarafından İzmir ili Kemalpaşa ilçesinde yapılan çalışmada yetiştiricilerin yaş ortalaması 50,3 olarak bildirilmiştir.

Çizelge 1. Yetiştiricilerin yaş dağılımları
Table 1. Age distribution of farmers

Yaş aralığı	Arıcı sayısı	Yüzdesi (%)	Yaş ortalamaları		
			Göçer	Sabit	Genel
39-50	16	18,40			
51-60	37	42,50	57,57	59,44	58,64
60+	34	39,10			
Toplam	87	100,00			

Çizelge 2. Araştırma katılan arıcıların eğitim düzeyi, aile üye sayısı ve arıcılık tecrübesi dağılımı
Table 2. Distribution of beekeepers' education level, number of family members and beekeeping experience

	N	%
Eğitim düzeyi		
İlkokul	15	17,20
Lise	28	32,20
Ortaokul	38	43,70
Üniversite	6	6,90
Toplam	87	100,00
Aile Üye Sayısı	N	%
2	30	34,50
3	22	25,30
4	28	32,20
5	7	8,00
Toplam	87	100,00
Arıcılık Tecrübesi	N	%
5-10	15	17,20
11-20	39	44,80
20+	33	37,90
Toplam	87	100,00

Çizelge 3. Arıcılıktaki amaç
Table 3. Purpose of beekeeping

Arıcılıktaki amaç	Arıcı Sayısı	Oran (%)
Ek gelir kaynağı	77	88,50
Esas geçim kaynağı	9	10,30
Meşgul olmak için yapıyor	1	1,20
Toplam	87	100,00

Yetiştiricilerin eğitim durumları Çizelge 2'de görüldüğü gibi, %43,7'si ortaokul, %32,2'si lise, %17,2'si ilkokul ve %6,9'u üniversite mezunudur. Kars, Ardahan, Iğdır ve Ağrı illerini içine alan TRA2 bölgesinde yapılan çalışmada, yetiştiricilerin %51'inin lise veya yüksekokul diplomasına sahip olduğunu ortaya koymuştur (Sezgin ve Kara, 2011). Çivi Yalçın (2014) tarafından Tokat ilinde yapılan bir çalışmada, lisans veya lisansüstü dereceye sahip yetiştiricilerin oranı %44,5'tir. Türkoğlu (2001) tarafından Tokat'ta yapılan bir başka çalışmada ise yetiştiricilerin %35'inin lise, %36'sının ise yüksek lisans mezunu olduğu tespit edilmiştir. Tunca ve Çimrin (2012) tarafından Kırşehir ilinde ikamet eden 47 yerli arıcı ile yaptığı araştırmada %31'inin lise mezunu olduğu bildirilmiştir.

Arıcılıkla uğraşanların hane halkı kişi sayıları Çizelge 3'de verilmiştir. Katılımcıların %34,5'i 2 kişi, %25,3'ü 3, %32,2'si 4 ve %8,0'i ise 5 kişilik hane halkından oluştuğu tespit edilmiştir.

Ankete katılan arıcıların %17,2'si 5-10 yıl, %44,8'i 11-20 yıl ve %37,9'u ise 20 yıl ve üzeri arıcılık yaptıkları belirlenmiştir (Çizelge 4). Saner ve arkadaşları (2011) tarafından İzmir Kemalpaşa'da yapılan çalışmada, çalışmaya katılan üreticilerin ortalama arıcılık deneyimi 11,08 yıl olarak belirlenmiştir. Çivi Yalçın (2014) tarafından Tokat ili merkez ilçesinde yapılan araştırmada ise üreticilerin ortalama 16,95 yıl arıcılık deneyimine sahip oldukları belirlenmiştir. Demen (2015) tarafından Diyarbakır'da yapılan bir çalışmada ise ortalama arıcılık tecrübesi 13,83 yıl olarak bildirilmiştir. Benzer şekilde, Şahinler ve Gül (2003) tarafından Hatay'da yapılan bir çalışmada, ortalama arıcılık deneyiminin 10,5 yıl olduğu bildirilmiştir. Kutlu ve ark. (2016) tarafından Türkiye genelinde; Kekeçoğlu vd (2007) tarafından 38 farklı ilde yürütülen çalışmada, üreticilerin yaklaşık olarak %75'inin 10 yıl ya da daha fazla süredir arıcılık yaptıkları saptanmıştır

Arıcıların arıcılık yapma nedenleri Çizelge 3'de verilmiştir. Arıcılıkla uğraşanların %88,5'i arıcılığı ek gelir kaynağı olarak, %10,3'ü esas geçim kaynağı olarak ve %1,2'si meşgul olmak için yaptığını belirtmiştir. Karahan ve Karaca (2016) tarafından Adana ve Konya illerinde yapılan çalışmada Adana'da arıcıların %59'u, Konya ilinde ise %21'i sadece arıcılıkla uğraşmakta ve geçimini arıcılıktan sağladığı bildirilmiştir. Üçeş ve Erişir (2016) tarafından Erzincan ilinde yapılan çalışmada %38,28'inin birincil iş, %60,49 ikincil ve %1.23'ünün ise hobi amaçlı arıcılıkla ilgilendikleri bildirilmiştir. Tunca ve Çimrin (2012) tarafında Kırşehir'de yapılan bir çalışmada yetiştiricilerin %17'si tek gelir kaynağı, %57'si ek gelir sağlamak amacıyla arıcılık yaptığı belirtilmiştir.

Arıcıların Kovan Sayıları

Arıcıların kullandıkları toplam kovan sayıları 1-25, 26-50, 51-75, 76 ve üzeri olmak üzere gruplandırılarak oranları Çizelge 4'de, ayrıca göçer ve sabit arıcıların sahip oldukları ortalama kovan sayıları Çizelge 5'de verilmiştir. Çizelge incelendiğinde, arıcıların %33,3'ü 26-50 adet, %32,2'si 51-75 adet ve %20,7'si 76 ve üzeri kovana sahip oldukları tespit edilmiştir.

Çizelge 5 incelendiğinde, göçer arıcıların ortalama kovan sayıları 75,68 adet, sabit arıcıların ortalama kovan sayıları 53,86 adet ve çalışmaya katılan arıcıların ortalama kovan sayısı ise 63,14'dür. Yaşar ve ark., (2002) Karadeniz Bölgesi arıcılığının genel yapısının belirlenmesine yönelik çalışmalarında, bölgede işletme başına ortalama koloni sayısını 63 olarak bulunmuştur. Çakmak ve ark., (2003) Güney Marmara Bölgesinde arıcılığın genel sorunlarını belirlemek amacıyla yaptıkları çalışmada; ortalama kovan sayısı 72 adet olarak bulunmuştur.

Göçer ve Sabit Arıcıların Sahip Oldukları Ana Arı Irkları

Arıcıların sahip oldukları ana arı ırkları Çizelge 6'da gösterilmiştir. Göçer ve sabit arıcıların ana arı ırkları incelendiğinde yoğun olarak Karniyol, Kafkas, İtalyan ve Melez arıların kullanıldığı tespit edilmiştir. Göçer arıcılar yoğunlukla %43,2 oranında Karniyol arı, %19,3 oranında Kafkas ve %17,8 oranında ise İtalyan ana arı ırkını tercih ettiklerini, sabit arıcıların ise yoğun olarak %50,5 oranında Kafkas, %23,8 oranında İtalyan ve %20,01 oranında ise Melez ana arı ırklarını tercih ettikleri tespit edilmiştir. Karniyol ırkı, arı ırkları içerisinde en uysal (Kaftanoğlu, 1994), çok çalışkan ve yağmacılık eğilimi oldukça az olan bir ırktır. Ancak oğul verme eğilimi yüksektir (Öztürk ve Korkmaz, 2005). Göçer arıcıların Karniyol ırkını çalışkanlık, uysallık ve bal veriminin yüksek olması gibi özellikleri nedeniyle tercih etmektedirler. Bununla birlikte Karniyol ırkında ana arı tutumunun zor ve bakımının fazla olması nedeniyle özellikle kovan sayısı az olan ve bakım için yeteri kadar zaman ayıramayan arıcılar Karniyol ırkını bu nedenle tercih etmediklerini bildirmişlerdir.

Kuzeydoğu Anadolu'nun yerli arısı olan Kafkas arısı (*Apis mellifera caucasiae*), uysal davranışları ve yüksek bal verimi ile ünlüdür. Dünya genelinde birçok bölgede, özellikle de yüksek rakımlı alanlarda yoğun olarak yetiştirilmektedir (Genç ve ark., 1999; Adl ve ark., 2007; Güler, 2010). Türkiye'de arıcılar tarafından kullanılan ticari ana arılar saf bir genotipe ait olmayıp, çoğunlukla Kafkas ve Anadolu arıları olmak üzere diğer ırk ve ekotiplerin melezlerinden oluşmaktadır (Gösterir ve ark., 2012). Kafkas arısının en önemli özelliği düşük oğul kalitesidir (Anonim, 2007). Sabit arıcıların çoğunlukla Kafkas ırkını tercih etmelerinin sebebinin ise bu ırkla çalışmanın rahat olmasının yanında Kafkas ana arı temininin kolay olması ve kültürel alışkanlıklar bu ırkı tercih etmelerinin başlıca sebepleridir. Kuzeydoğu Anadolu Bölgesi'nde yapılan bir çalışmada, arılıkların %74,5'inde Kafkas arısı, %24,1'inde melez ırk ve %1,4'ünde Karniyol arısı yetiştirildiği ortaya çıkmıştır (Sezgin ve Kara, 2011). Türkiye genelinde yapılan bir çalışmada, arıcılık işletmelerinin %25,33'ünün Anadolu arısı, %21,33'ünün Kafkas arısı, %9'unun Karniyol arısı ve %5,33'ünün melez ırk arı yetiştirdiği, %39'unun ise yetiştirdiği arı ırkı hakkında bilgisi olmadığı (Kekeçoğlu ve ark., 2007). Öztürk ve arkadaşları (2012) tarafından Akdeniz bölgesinde yapılan çalışmada, arıların %39,57'sinin Karniyol, %27,3'ünün İtalyan ve %22,3'ünün Kafkas çeşidi olduğu bildirilmiştir.

Arıcılıkta Karşılaşılan Sorunlar

Üreticilerin karşılaştıkları sorunlar incelendiğinde ilk sırada %29,9 oranında ayı riski, %23 oranında olumsuz iklim koşulları, %18,4 oranında pazarlama sorunları ve %11,5 oranında girdi fiyatları gelmektedir. Karşılaşılan sorunlarda ilk sırada ayı riski gelmesinin sebebi, her ne kadar üreticiler kendilerince tedbir almakla birlikte ayı saldırısı gerçekleştiğinde hem kovan ve diğer malzemeler, arı kolonisi ve bal olmak üzere tamamında geri dönüşü olmayan kayıp yaşandığı için ayı saldırısı üreticilerin en fazla zarara uğratan sorun olmaktadır.

Çizelge 4. Arıcıların kovan sayısı
Table 4. Number of beekeepers' hives

Kovan sayısı (dolu+boş) (adet)	Arıcı Sayısı	Oran (%)
1-25	12	13,80
26-50	29	33,30
51-75	28	32,20
76+	18	20,70
Toplam	87	100,00

Çizelge 5. Arıcıların Ortalama Kovan Sayıları
Table 5. Average Number of Hives of Beekeepers

	Ortalama Kovan Sayıları (dolu+boş) (adet)
Göçer	75,68
Sabit	53,86
Bütün Arıcılar	63,14

Çizelge 6. Ana arı bilgileri
Table 6. Queen bee information

Ana Arı Irkı	Karniyol			Kafkas			İtalyan			Melez			Bilinmeyen		
	Adet	%	Yaş	Adet	%	Yaş	Adet	%	Yaş	Adet	%	Yaş	Adet	%	Yaş
Göçer	56,2	43,2	2,3	25,1	19,3	2,6	23,1	17,8	2,4	12,4	9,6	2,1	13,3	10,2	2,0
Sabit	3,5	5,6	2,0	31,7	50,5	2,8	14,9	23,8	2,6	12,7	20,1	2,8	0,0	0,0	0,0
Ortalama	48,6	39,2	2,3	29,6	23,9	2,7	19,9	16,0	2,5	12,6	10,1	2,6	13,3	10,7	2,0

Çizelge 7. Arıcıların sorunları
Table 7. Problems of beekeepers

Karşılaşılan Sorunlar	Sayı	Yüzde (%)
Ayı riski	26	29,9
Olumsuz iklim koşulları	20	23,0
Pazarlama sorunları	16	18,4
Girdi fiyatları	10	11,5
Mera alanlarının bozulması	7	8,0
Arı hastalıkları	5	5,7
Diğer sorunlar	3	3,4
Toplam	87	100

Çizelge 8. Alet ekipman varlığı
Table 8. Presence of instrument equipment

S.N	Gider kalemleri	Adet				Birim fiyat		Yaş	
		Göçer		Sabit		Göçer	Sabit	Göçer	Sabit
		Ort.	Arıcı	Ort.	Arıcı				
1	Boş Kovan	22,97	37	13,30	50	936,49	766,00	8,43	8,72
2	Dolu Kovan (Koloni)	52,57	37	40,56	50	3.931,08	3.900,00	6,73	6,70
3	Süzme makinesi 3'lü/4'lü/8'li	1,00	24	1,00	26	4.604,17	2.603,85	9,50	9,54
4	Arıcı maskesi	2,38	37	2,12	50	192,97	186,20	3,51	4,20
5	Bal dinlendirme kabı	1,00	13	1,00	14	2.607,69	1.267,86	5,69	6,93
6	Bal ısıtma kazanı	1,25	4	1,00	7	8.625,00	2.021,43	7,25	7,43
7	Yemlik	62,22	37	51,70	50	11,89	14,68	4,05	4,22
8	Ruşet kovan	50,00	4	16,00	5	762,50	900,00	6,00	6,40
9	Arıcı fırçası	2,00	37	1,70	50	46,35	48,20	3,51	3,20
10	Arıcı körüğü	2,24	37	2,40	50	163,24	165,80	3,73	4,28
11	Çıta delme makinesi	1,08	25	1,00	39	360,80	357,69	4,96	5,05
12	Bal bıçağı ve sır tarağı	1,67	36	1,64	47	88,06	87,66	3,71	4,77
13	Bölme tahtası	66,89	37	54,48	50	14,49	12,28	3,27	3,52
14	Ana arı kafesleri	85,71	7	16,88	8	8,57	10,63	3,29	2,75

Çizelge 9. Malzeme bilgileri
Table 9. Material information

	Gider kalemleri	Adet				Birim fiyat		Yaş	
		Göçer		Sabit		Göçer	Sabit	Göçer	Sabit
		Ort.	Adet	Ort.	Adet				
1	Temel petek	48,81	36	58,04	50	141,94	156,80	1,17	1,16
2	Çerçeve teli	2,50	22	1,34	40	124,55	113,63	1,27	1,48
3	Eldiven	1,50	22	1,18	34	13,64	13,09	1,09	1,21
4	Teneke/Kavanoz	161,94	36	103,00	50	12,75	12,54	1,08	1,20
5	Alet Mak. Tamir Bakım Masrafı	1,00	36	1,00	50	901,39	607,00	1,00	1,00

Arıcılık Üretim Dalının Yatırım Giderleri (Alet Ekipman Varlığı)

Arıcıların alet ekipman varlıkları Çizelge 8'de gösterilmiştir. Göçer arıcılarda boş ve dolu kovan(koloni), arıcı maskesi, bal ısıtma kazanı, yemlik, ruşet kovan, arıcı fırçası, bal bıçağı ve sır tarağı, bölme tahtası, ana arı kafesi gibi alet ve ekipman varlığı ortalamaları sabit arıcılara göre fazladır. Göçer arıcılarda alet ve ekipmanların taşınmadan kaynaklı daha fazla yıpranmaları sonucu malzemelerin daha sık yenilenmesi nedeniyle, alet ekipman yaş ortalamaları sabit arıcılarınkinden daha düşüktür.

Arıcılık Üretim Giderleri

Arıcıların sezondaki üretim miktarına göre değişim gösteren temel petek, çerçeve teli, eldiven, teneke/kavanoz gibi üretime bağlı malzeme bilgileri çizelge 9'da verilmiştir. Sabit arıcılarda temel petek kullanım oranı göçer arıcılardan fazladır. Bunun sebebi sabit arıcıların göçer arıcılara göre yazın bal sezonundan süre olarak daha fazla yararlandıkları için temel petek kullanımları fazladır. Göçer arıcıların ekipman, alet ve makine tamir bakım masrafları sabit arıcılara göre %48,5 oranında daha fazladır. Bu durumun nedeni, göçer arıcıların bu malzemelerinin nakiller sırasında daha fazla yıpranmasından kaynaklı olarak yapılan tamir bakım masrafları sabit arıcılardan fazladır. Bunlarla birlikte göçer arıcılarda malzemelerin daha sık yenilenmesi nedeniyle, malzeme yaş ortalamaları sabit arıcıların malzeme yaş ortalamalarından daha düşüktür.

Arıcılık Faaliyetlerinin Ekonomik Analizi

Arıcılık işletmelerinin üretim masrafları ve masraf unsurları çizelge 10'da incelenmiştir. İncelenen arıcılık işletmelerinde işletme başına toplam değişken masraf sabit arıcılara göre göçer arıcılarda %28 daha fazladır. İşletme başına toplam sabit masraflar göçer arıcılara göre sabit arıcılarda %7,29 oranında daha fazladır. İşletme başına toplam masraflar sabit arıcılarda 59.687,44 TL ve göçer arıcılarda 65.751,25 TL'dir.

Çizelge 10. İncelenen Arıcılık İşletmelerinde İşletme Başına Üretim Masrafları (TL)
Table 10. Production Costs per Enterprise in the Analyzed Beekeeping Enterprises (TL)

		Arıcılık Türü	
		Sabit Arıcılık	Göçer Arıcılık
Besleme giderleri	İlkbahar	5533,80	7745,95
	Sonbahar	4735,60	4421,62
Toplam Besleme Giderleri		10269,40	12167,57
Pazarlama		1442,20	2792,70
Nakliye yakıt		2,00	3089,19
Arıcı konaklama		40,00	500,00
Arı bakım ve ilaçlama		264,70	376,35
Temel petek masrafı		9167,50	6947,03
Alet tamir ve bakım		607,00	877,03
Geçici işçilik masrafı		210,00	1418,92
Döner sermaye faizi (%3,75)		825,11	1056,33
Değişen masraflar toplamı		22827,91	29225,11
Genel İdari Giderler (%3)		878,27	814,21
Bakım aile işgücü		8918,13	7984,80
Konaklama		16082,50	12067,57
Hasat aile işgücü		4275,00	7087,84
Sabit masraflar toplamı		30153,89	27954,41
TOPLAM MASRAFLAR		52981,80	57179,52
Ortalama Üretim Miktarı (kg)		373,40	533,38
1 Kg Bal Maliyeti		141,89	107,20
1 Kg Bal Satış Fiyatı		342,45	343,38
1 Kg Bal net kar		200,56	236,18
Kovan başı ortalama masraf		1409,75	1007,83

Çizelge 11. İncelenen Arıcılık İşletmelerinde İşletme Başına Düşen GSÜD (TL)
Table 11. GDP per Enterprise in the Analyzed Beekeeping Enterprises (TL)

	Arıcılık Türü	
	Sabit Arıcılık	Göçer Arıcılık
Süzme Bal GSÜD	74547,20	121445,46
Petek Bal GSÜD	52603,74	60731,06
Devlet Desteği	1216,80	1577,03
TOPLAM GSÜD	128367,7	183753,6

Çizelge 12. İncelenen Arıcılık İşletmelerinde Kovan Başına Düşen GSÜD (TL)
Table 12. GDP per Hive in the Analyzed Beekeeping Enterprises (TL)

	Arıcılık Türü	
	Sabit Arıcılık	Göçer Arıcılık
Bal GSÜD	3152,63	3484,12
Devlet Desteği	30,00	30,00
Toplam GSÜD	3182,63	3514,12

İşletmelerde üretim masraflarında en fazla paya, besleme giderleri, bakım-konaklama aile işgücü, temel petek gideri ve hasat aile işgücü sahiptir. İşletme başına ortalama bal üretim miktarında sabit arıcılara göre göçer arıcılar %42 oranında daha fazladır. Kovan başına toplam masraf sabit arıcılarda göçer arıcılara göre daha fazladır.

Arıcılık işletmelerinde işletme başına düşen GSÜD çizelge 11'de incelenmiştir. Arıcılık işletmelerinde GSÜD, üretilen süzme ve petek balın satış fiyatı ile çarpılması sonucu elde edilmiştir. Ayrıca GSÜD'ye devlet destekleri de eklenmiştir. İşletmelerde bal dışında arı ürünü üretimine rastlanılmamıştır. Göçer arıcılıkta GSÜD 183.753 TL olarak hesaplanırken, sabit arıcılarda GSÜD 128.367 TL olarak hesaplanmıştır. GSÜD fark göçer arıcıların bal verimi yüksek bölgelerde arılarının yaymalarından kaynaklanmaktadır.

Kovan başına düşen GSÜD incelendiğinde, göçer arıcılık yapan işletmelerin kovan başına GSÜD'nin sabit arıcılık yapan işletmelere göre yaklaşık %10 daha fazla olduğu tespit edilmiştir. göçer arıcılarda kovan başına GSÜD 3514 TL iken, sabit arıcılarda kovan başına GSÜD 3182 TL olarak hesaplanmıştır.

Sonuç ve Öneriler

Arıcıların çoğunlukla 50 yaş üzeri olması, genç nüfusun arıcılık yapma konusunda fazla istekli olmadıklarını, arıcılığın ek gelir ve emeklilikten sonra yapılan bir uğraş olarak daha çok benimsendiğini göstermektedir. Arıcılık faaliyetlerinin genç bireyler arasında özendirilecek teşvikler verilmesi, projeler ve programlar yapılması sektöre dinamiklik katacak ve genç nüfusun istihdamına katkı sağlayacaktır.

Çalışma alanındaki kovan başına ortalama bal verimi 9,67 kg olarak tespit edilmiştir. Türkiye'nin ortalama bal verimi 2022 yılında 13,17 kg'dır. Bölgedeki kovan başına ortalama bal üretim miktarı Türkiye ortalamasının altında olduğu görülmüştür.

Bölgede bitkisel üretim faaliyetleri sınırlı alanlarda gerçekleşmektedir. Bunun yanında bal bitkisi niteliğindeki bitkisel üretimde aynı düzeyde yok denecek seviyededir. Buna bağlı olarak bölgede arıcılıkta bal üretimi çoğunlukla doğal mera alanlarındaki bitki yapısına ve iklim koşullarına bağlıdır. Mera alanlarında arılarında yararlanabileceği bal bitkisi niteliğindeki korunga, yonca gibi bitkisel üretimin tarla vasfındaki uygun yerlerde yapılması bal verimini artıracaktır. Bu yönde tarım teşkilatlarının projeler geliştirmesi, bal üretim miktarını ve kalitesini artıracaktır.

Bölgede arıcılık faaliyetini destekler nitelikte kooperatif bulunmamaktadır. Daha öncesinde arıcılık üzerine bir kooperatif kurulmuş ancak yeteri kadar kooperatif bilinci oluşmadığından faaliyeti devam ettirilememiştir. Bölgede arıcılık faaliyeti üzerine kooperatif kurulması halinde sektöre üretim ve pazarlama konusunda faydası olacaktır. Bölgedeki arıcılar ürettikleri balın kalitesine ve lezzetine güvendiklerini belirtmektedirler ancak, yörede belirlenen bal satış fiyatı ile başka bölgelere ait daha düşük fiyatlı ballara karşı yöre balının rekabet edebilmesi için kalite kriteri üzerinden daha fazla tanıtıma ihtiyacı vardır. Böylelikle yöre balının kalite yönünden korunması teşvik edilmiş olacaktır. Arıcıların şikayetleri arasında bölgeye dışarıdan farklı kalitedeki düşük fiyatlı ballarında getirilerek satılıyor olmasıdır.

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Investigation of the Effect of Thyme Oil Addition to Quail Rations on Egg Production and Quality Characteristics by Discriminant Analysis

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ABSTRACT

In this study, the effects of different levels of thyme oil supplementation in the diets of Japanese quails on egg quality parameters were evaluated. A total of 90 Japanese quails (Coturnix coturnix Japonica) (aged 16 weeks), were randomly assigned to one of three experimental groups: a control group, a low thyme group (receiving 150 mg/kg), and a high thyme group (receiving 300 mg/kg). The internal and external quality characteristics of the eggs were analyzed. The ANOVA results demonstrated significant intergroup differences in eggshell ratio, shape index, and yellow color. Discriminant analysis was employed to ascertain the extent of separation between the groups in terms of egg quality parameters, revealing that some parameters exhibited significant intergroup differences. The findings suggest that thyme oil can positively influence egg quality at specific dosages; however, high dosages may have adverse effects.

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Bıldırcın Rasyonlarına Kekik Yağı İlavesinin Yumurta Verimi ve Kalite Özelliklerine Etkisinin Diskriminant Analizi ile İncelenmesi

MAKALE BİLGİSİ

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ÖZ

Çalışmada, Japon bıldırcınlarının (*Coturnix coturnix Japonica*) yemlerine farklı oranlarda kekik yağı ilavesinin yumurta kalite parametreleri üzerindeki etkileri incelenmiştir. Çalışma, 6 haftalık yaşta 72 dişi Japon bıldırcını üzerinde gerçekleştirilmiştir ve bıldırcınlar kontrol, düşük kekik yağı (150 mg/kg) ve yüksek kekik yağı (300 mg/kg) gruplarına ayrılmıştır. Rasyona farklı oranlarda kekik yağı eklenmesinin bazı yumurta dış ve iç kalite parametreleri üzerine etkileri istatiksel olarak incelenmiştir. Yapılan tek yönlü varyans analizi (ANOVA) sonucundayumurta kabuk oranı, şekil indeksi ve sarı rengi gibi parametrelerin gruplar arasında istatiksel olarak anlamlı farklılıklar gösterdiği belirlenmiştir ($P<0,05$). Çalışmada elde edilen veriler, ANOVA sonrasında, Diskriminant analizi ile de incelenmiş ve grupların yumurta kalite parametreleri bakımından gruplanmaları belirlenmiştir. Diskriminant analizi sonucunda iki fonksiyon tanımlanmıştır. İlk fonksiyonda, düşük kekik grubunun diğer gruplardan belirgin bir şekilde ayrıldığı; özellikle kabuk ağırlığı ve pH bakımından farklılık olduğu belirlenmiştir. İkinci fonksiyonda ise kontrol ve yüksek kekik grupları arasında önemli ayrım tespit edilmiştir. Her iki fonksiyonda da ANOVA sonuçlarına benzer şekilde yumurta sarı rengi bakımından gruplar arasında farklılık gözlenmiştir. Sonuçlar, kekik yağının 150 mg/kg dozunda yem katkı maddesi olarak kullanılmasının yumurta kalitesini olumlu yönde etkileyebileceğini, ancak bıldırcın rasyonuna 300 mg/kg kekik yağı ilavesinin olumsuz sonuçlar doğurabileceğini göstermektedir.

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Giriş

Günümüzde insan beslenmesinde hayvansal protein kaynakları, artan dünya nüfusunun gıda ihtiyacını karşılamak amacıyla büyük bir önem taşımaktadır. Artan popülasyon talebine yanıt olarak, üretim süresinin kısa olması, ürünlerin her kültür ve inanç grubu tarafından kabul görmesi ve kolayca ulaşılabilir olması gibi avantajlarıyla kanatlı ürünleri, hayvansal protein kaynakları arasında ön plana çıkmaktadır (Kırkpınar ve Erkek, 2000; Langhout, 2000). Bu bağlamda, kanatlı ürünleri başta tavuk eti olmak üzere önemli bir konumda yer almakta, hindi, kaz, bıldırcın gibi türler ise alternatif kanatlı olarak öne çıkmakta ve ürünleri, tüketici talebi açısından en az tavuk ürünleri kadar rağbet görmektedir.Kanatlı ürünlerinin sahip olduğu bu avantajlara karşın, tüketim sürecinde karşılaşılan bazı sağlık ve güvenlik sorunları dikkat çekmektedir. Kanatlı eti ve yumurtasının üretim süreçleri sırasında, koruyucu ve tedavi edici veteriner hekimlik uygulamalarında kullanılan antimikrobiyal ve antikoksidial maddeler, insan sağlığı üzerinde olumsuz etkiler yaratma potansiyeline sahiptir. Özellikle kısa üretim süresine sahip etlik piliçlerden elde edilen kanatlı eti ve tavuk yumurtalarında bu tür kimyasalların kalıntı bırakma riski, halk sağlığı açısından endişe kaynağı olmaktadır (Kırkpınar ve Erkek, 2000; Langhout, 2000; Çimrin ve ark., 2012; Yeşilbağ, 2018). Bu nedenle, kanatlı üretiminde kullanılan kimyasal katkı maddelerine alternatif olarak, insan sağlığına zararlı etkileri minimuma indirmek amacıyla çeşitli organik bileşikler önerilmektedir. Bu organik bileşikler, antimikrobiyal ve antikoksidial özellikler taşıyarak, üretim süreçlerinde kullanılan kimyasal ürünlerin yerini alabilecek güvenilir alternatifler sunmaktadır. Güncel araştırmalar, özellikle bitkisel bazlı katkı maddelerinin kanatlı ürünlerinin kalitesini artırmada ve sağlık risklerini azaltmada etkili olduğunu ortaya koymaktadır. Bu yaklaşım, hem üreticiler hem de tüketiciler tarafından daha sağlıklı ve güvenilir kanatlı ürünleri tüketilmesine imkan tanımaktadır (García-Ruiz ve ark., 2020; Kırkpınar ve Erkek, 2000; Yeşilbağ, 2018). Antibiyotiklerin performans arttırıcı özelliklerinden faydalanılması amacıyla kullanımına getirilen kısıtlama sonrasında özellikle aromatik bitkiler ve uçucu yağların kanatlı beslemede kullanımı gün geçtikçe artış göstermektedir (Çimrin ve İrgin Tunca, 2012). Esansiyel yağların kimyasal bileşimleri ve bileşenlerinin konsantrasyonları ve dolayısı ile biyolojik etkileri de geniş bir varyasyon göstermektedir. Etken maddelerine göre değişmekle birlikte aromatik bitki ekstratlarının (diğer adı ile esansiyel yağlar) antimikrobiyal, antiviral, antiparaziter, insektisidal, antifungal, karminatif, koloretik, sedatif, diüretik, antispazmodik ve antioksidan etkiler gösterdiği çeşitli çalışmalarla ortaya konmuştur(Bilal ve ark., 2008; Şengezer ve Güngör, 2008; Giannenas ve ark., 2013; Karakullukçu ve ark., 2016). Aromatik bitkiler ve bunlardan elde edilen uçucu yağların sindirim sisteminde enzim miktar ve aktivitesini artırdığı, bağırsaktaki mikrobiyal floranın regülasyonunu sağladığı, bağışıklık sistemini kuvvetlendirdiği ve antioksidan etkisinden dolayı ürünlerin raf ömrünü artırdığı dolayısı ile hayvan beslemede yem katkı maddesi olarak kullanılabileceği bildirilmektedir (Giannenas ve ark., 2013; Karakullukçu ve ark., 2016).

Bitkisel ekstraktlar içerisinde antimikrobiyal etkisi sebebiyle en fazla kullanılan ve en çok bilinen ekstrakt kekik uçucu yağıdır. Kekik uçucu yağında en fazla bulunan antibakteriyel bileşikler fenolik yapıdaki karvakrol ve timoldür (Botsoglou ve ark., 2003; Parlat ve ark., 2005). Kekik ve aktif bileşenlerinin amilaz, proteaz ve lipaz gibi sindirim enzimlerini uyararak sindirilebilirliği artırdığı bildirilmektedir (Abdel-Wareth, 2011; Abdel-Wareth ve ark., 2013). Aynı zamanda, *Labiotae* familyasına ait kekik türlerinindezenfektan olarak kullanımı, bağırsak uzunluğu ile villus derinliği ve genişliğini artırarak sindirim ve emilimi iyileştirmekte; bu sayede de besinlerin emilimini artırmaktadır (Alçiçek ve ark., 2003).

Bitki ekstraktları ve uçucu yağlarının kanatlı hayvan yetiştiriciliğinde çeşitli performans parametreleri üzerinde olumlu etkiler sağladığı göz önüne alınarak farklı kanatlı türlerinde denemeler yapılmıştır. Damızlık broylerler üzerinde yapılan bir araştırmada, kekik yağı, defne yaprağı yağı, adaçayı yaprağı yağı, mersin yaprağı yağı, rezene tohumu yağı ve narenciye yağından oluşan bir uçucu yağ karışımının, canlı ağırlık, yumurta ağırlığı ve yumurta verimi üzerinde belirgin bir etkisi olmadığı, ancak kuluçkalık yumurtalarda döllülük oranını artırdığı gözlemlenmiştir (Bozkurt ve ark., 2009). Bu bulgu, doğal uçucu yağların üreme performansını olumlu yönde etkileyebileceğini göstermektedir. Yumurta tavukları üzerinde yapılan bir başka çalışmada ise, mannan oligosakkarit ve mersin bitkisi yağını içeren bir esansiyel yağ karışımının yumurta kabuk ağırlığını iyileştirdiği tespit edilmiştir. Bununla birlikte, bu yağ karışımının yumurta ağırlığı, yem tüketimi, yemden yararlanma oranı, kabuk kalınlığı ve kabuk ağırlığı gibi diğer performans parametreleri üzerinde belirgin bir etkisi olmadığı bildirilmiştir (Bozkurt ve ark., 2012). Behnamifar ve ark. (2015), bıldırcın yumurtalarının kalite ve miktarını artırmak amacıyla kekik, kimyon ve sarımsak ekstraktlarının etkilerini incelemiştir. Araştırma sonucunda, kekik ve sarımsak gruplarında yumurta sarısı ve serum kolesterol düzeylerinin azaldığı gözlemlenmiştir. Ayrıca, El-Hindawy ve ark. (2021), Japon bıldırcınlarının verim ve üreme performansının çeşitli kekik türlerinin ve protein seviyelerinin etkisiyle iyileştirilebileceğini ortaya koymuştur. Çalışmada %20 ve %22 protein içeren diyetlere kekik veya dağ kekiği yağı ilavesi yapılmış ve bu gruplarda yumurta sayısında, yumurta kütlesinde ve yemden yararlanma oranında belirgin bir artış tespit edilmiştir. Rasyona kekik yağı katkısının, tüm deneme dönemlerinde bıldırcınların üretim performansı üzerinde olumlu bir etkisi olduğu belirtilmiştir. Bu araştırmalar, belirli uçucu yağ karışımlarının ve bitkisel katkıların, kanatlı hayvanların üreme ve bazı ürün kalite özelliklerini iyileştirme potansiyeline sahip olduğunu ortaya koymakta, doğal katkıların kullanımıyla ilgili artan ilgiyi desteklemektedir.Diskriminant analizi, birden fazla bağımlı değişken arasında gruplar arasındaki ayrımı en iyi sağlayan değişkenleri belirlemek amacıyla kullanılan güçlü bir istatistiksel yöntemdir (Manly ve Manly, 1994).

Bu analiz, özellikle gruplar arasındaki sınıflandırma ve ayrım süreçlerinde kullanılır ve gruplar arasındaki farkları belirlemek için optimal bir yöntem sunar (Ramayah ve ark., 2010). Diskriminant analizinde, gruplar arasındaki en büyük ayrımı sağlayan doğrusal kombinasyonlar (diskriminant fonksiyonları) oluşturulur ve bu fonksiyonlar

kullanılarak, gözlemlerin belirli bir gruba ait olma olasılığı tahmin edilir (Cuadras ve Auge, 1981). Bu analiz yöntemi, özellikle çoklu bağımsız değişkenlerin birlikte değerlendirilmesi gerektiğinde ve gruplar arasındaki farkları daha kapsamlı bir şekilde ortaya koymak için tercih edilir (Chan, 2005). Diskriminant analizi, örneğin bitkisel katkı maddelerinin farklı hayvan gruplarındaki etkilerini incelemek için yaygın olarak kullanılmaktadır (Smith ve ark., 2020). Özellikle ANOVA'nın ortalama farkları belirlemede sınırlı kalabildiği durumlarda, diskriminant analizinin gruplar arasındaki farkları açıklamada daha detaylı ve kapsamlı sonuçlar sunduğu bilinmektedir (Ramayah ve ark., 2010; Smith ve ark., 2020).

Bu çalışmanın amacı, bıldırcın yemlerine farklı düzeylerde kekik yağı ilavesinin yumurta kalite parametreleri üzerine etkilerini daha derinlemesine inceleyerek gruplar arasındaki ayrımı diskriminant analizi ile ortaya koymaktır.

Materyal ve Metot

Denemede Kullanılan Hayvan Materyali

Hayvan materyali olarak 6 haftalık yaşta toplam 72 dişi Japon bıldırcını *(Coturnix coturnix japonica)* kullanılmıştır. Denemede kullanılacak hayvan sayısı, literatür örnek büyüklükleri dikkate alınarak belirlenmiştir. Deneme, XXX Üniversitesi Kanatlı Üretim Birimi'nde tamamlanmıştır. Yem ve su *ad libitum* olarak verilmiştir. Çalışmada bazal rasyon olarak %16,88 HP ve 2701 ME, Kcal/kg içeren yumurta yemi kullanılmıştır.Çalışma süresince tüm hayvanlara konfor sıcaklığı (24 °C) ve yumurta veriminin uyarımı için günde 18 saat aydınlık, 6 saat karanlık uygulanmıştır. Çalışmada gruplandırma kontrol grubu (K), yüksek grubu kekik (YK) ve düşük kekik grubu (DK) olmak üzere 3 grup şeklinde yapılmış ve gruplara sırasıyla bazal rasyona ilave olarak 0, 150 ve 300 mg/kg kekik uçucu yağı ilave edilmiştir. Her grup kendi içerisinde 3 alt gruba ayrılmış; her alt grup 100×45×20 cm ölçülerine sahip kafeslerde barındırılmıştır. Çalışma ilk yumurtaların görülmesini takiben 8 hafta süreyle devam etmiş ve sürenin sonunda sonlandırılmıştır.

Yumurta Veriminin Belirlenmesi

Çalışmada ilk yumurtanın görüldüğü 6. Haftadan çalışmanın sonuna kadar, yumurtalar 3 günde bir toplanmış ve sayım yapılmıştır. Çatlak ve kırık yumurtalar yumurta sayısına dahil edilirken, kabuksuz yumurtalar sayılmamıştır.

Yumurta Kalitesinin Belirlenmesi

Yumurtalarda bazı dış ve iç kalite özelliklerinin incelenmesi amacıyla, çalışmanın sonlandırılmasından üç gün önce yumurtalar her alt gruptan 3 yumurta olacak şekilde rastgele seçilerek yapılmıştır. Tüm yumurtaların ağırlıkları 0,01 g hassas terazi ile belirlenmiş, ardından kabuk yüzey alanı ve şekil indeksinin hesaplanması amacıyla yumurta uzunluk ve genişlik değerleri 0.01 mm hassas dijital kumpas ile ölçülmüştür. Yumurta şekil indeksinin hesaplanmasında Yannakopoulos ve Tserveni-Gousi (1986), formülünden faydalanılmıştır;

$$\text{Yumurta şekil indeksi (\%)} = \left(\frac{\text{Yumurta eni}}{\text{Yumurta boyu}}\right) \text{x } 100$$

Yumurta kabuk yüzey alanının (cm^2) hesaplanmasında *ise* Olawunmi ve Chiristiana (2017)'nın formülünden yararlanılmıştır.

$$\text{Kabuk yüzey alanı} = 3{,}9782 \text{ x } (\text{Yumurta Ağırlığı})^{0{,}7056}$$

Dış kalite özelliklerine ait ölçümlerin ve hesaplamaların tamamlanmasının ardından iç kalite özellikleri incelenmiştir. Bu amaçla, zarlı kabuk ağırlığı, ak yüksekliği, ak genişliği, ak uzunluğu, sarı yüksekliği, sarı genişliği, sarı uzunluğu, ak ağırlığı, sarı ağırlığı, ak indeksi, sarı indeksi, ak pH değeri, Haugh Birimi ve İç kalite birimi (IQU) olarak belirlenmiştir. Yapılacak hesaplamalarda aşağıda verilen formüllerden faydalanılmıştır.

$$\text{Kabuk oranı (\%)} = \frac{\text{Kabuk ağırlığı (g)}}{\text{Yumurta ağırlığı (g)}} \text{x} 100$$

(Kaya ve Aktan, 2011)

$$\text{Ak indeksi (\%)} = \frac{\text{Ak yüksekliği (mm)}}{(\text{Ak uzunluğu} + \text{Ak genişliği})/2} \text{x} 100$$

(Olawumi ve Chiristiana, 2017).

$$\text{Sarı indeksi (\%)} = \frac{\text{Sarı yüksekliği (mm)}}{\text{Sarı çapı (mm)}} \text{x} 100$$

(Yannakopoulos ve Tservani-Gousi, 1986).

$$\text{HB} = 100 \text{ x } \log(\text{AY} + 7{,}52 - 1{,}7 \text{ x } (\text{YA}^{0{,}37})$$

(Kaya ve Aktan, 2011).

HB : Haugh birimi
AY : Ak yüksekliği (mm)
YA : Yumurta ağırlığı (g)

$$\text{İKB} = 100 \text{ x } \log(\text{AY} + 4{,}18 - (0{,}8989 \text{xYA}^{0{,}6674}))$$

(Kaya ve Aktan, 2011).

İKB : İç kalite birimi (IQU,%)
AY : Ak yüksekliği (mm)
YA : Yumurta ağırlığı (g)

İstatistiksel Analizler

Veriler IBM SPSS Statistics (Version 27) paket programı kullanılarak analiz edilmiştir (IBM SPSS, 2020). Yumurta kalite parametreleri arasında gruplar arası farklılıkları belirlemek için Tek Yönlü Varyans Analizi (ANOVA) uygulanmıştır. Anlamlı bulunan sonuçlar için Post Hoc Tukey testi ile gruplar arası farklar detaylandırılmıştır. Ayrıca, gruplar arasındaki ayrımı belirlemek için Diskriminant Analizi yapılmıştır. Diskriminant analizinde, bağımlı değişken olarak deneme grupları (DK, YK, K) ve bağımsız değişkenler olarak yumurta kalite parametreleri kullanılmıştır. Bu analizde, grupların hangi bağımsız değişkenler ile en iyi şekilde ayrıldığı belirlenmiştir. Diskriminant fonksiyonlarının ayrım gücünü test etmek için özdeğerler (eigenvalues), kanonik korelasyonlar ve Wilks' Lambda değerleri belirlenmiş ve elde edilen sonuçlar Khi-kare testi ile doğrulanmıştır.

Bulgular

Çalışma süresinde gruplardan elde edilen yumurta sayıları Tablo 1'de verilmiştir.

8 haftalık deneme süresince kontrol, düşük kekik ve yüksek kekik gruplarına ait ortalama yumurta sayıları sırasıyla 165,62±13,485, 159,37±14,226 ve 120,37±7,461 olarak ölçülmüştür. İstatistiksel analiz sonuçlarına göre, kontrol grubu ile düşük kekik grubu arasında anlamlı bir fark bulunmazken (p>0,05), yüksek kekik grubundaki yumurta sayısının hem kontrol hem de düşük kekik grubuna kıyasla anlamlı derecede düşük olduğu tespit edilmiştir (p=0,031). Bu bulgular, yüksek kekik düzeyinin yumurta üretimi üzerinde olumsuz bir etkisi olabileceğini düşündürmektedir.

Yumurta dış kalite özelliklerine ait değerler Tablo 2'de verilmiştir. Yumurta ve kabuk ağırlığı açısından gruplar arasında istatistiksel olarak anlamlı bir fark bulunmamıştır Yüksek kekik grubu, düşük kekik ve kontrol gruplarına kıyasla biraz daha ağır yumurtalara sahip olsa da bu farklar istatistiksel olarak önemli olmamıştır (P=0,167). Kabuk ağırlığı açısından da gruplar arasında istatistiksel olarak anlamlı bir fark bulunmamıştır (P=0,148). Ancak şekil indeksi ve kabuk oranı bakımından gruplar arasında istatistiksel olarak anlamlı bir farklılıklar gözlenmiştir (P<0,001; P =0,021). Düşük kekik grubundaki kabuk oranının, yüksek kekik grubuna kıyasla daha yüksek (15,89 ± 0,789) olduğu, kontrol grubunun ise her iki grup arasında yer aldığı belirlenmiştir (14,17 ± 0,240). Yüksek kekik grubu ise en düşük kabuk oranına sahip olup (13,69 ± 0,436), kontrol grubuyla istatistiksel olarak anlamlı bir farklılık göstermiştir.

Yumurta iç kalite özelliklerine ait değerler Tablo 3'te verilmiştir. Kontrol ve yüksek kekik grupları benzer pH değerlerine sahipken (8,84 ve 9,02), düşük kekik grubunun pH değeri daha düşük bulunmuştur (8,37, P=0,002). Haugh Birimi bakımından gruplararası farklılık tespit edilememiştir (P=0,766). İç kalite birimi (IQU) açısından da gruplar arasında anlamlı bir fark bulunmamıştır (P=0,642).

Yumurta rengi bakımından ise gruplar arasında önemli farklılık elde edilmiş olup yüksek kekik grubunda yumurta rengi Roche skalasına göre 2 olarak puanlanırken, düşük kekik grubunda Roche skalası sarı rengi ortalama 3; kontrol grubunda ise 4 olarak belirlenmiştir.

Çalışmada, kekik yağı ilavesinin, incelenen yumurta kalite parametreleri üzerine etkileri, diskriminant analizi ile de değerlendirilmiştir. Bu analiz ile, grupların hangi değişkenler tarafından en iyi şekilde ayrıldığını belirlemenmiştir. Uygulanan modele ait model performans sonuçları Tablo 4'te verilmiştir.

Tablo 1. Çalışma süresince gruplardan elde edilen yumurta sayıları ($\bar{X} \pm S\bar{x}$)
Table 1. Egg numbers obtained from the groups during the study ($\bar{X} \pm S\bar{x}$)

Kontrol	Düşük kekik	Yüksek kekik	P
165,62±13,485[a]	159,37±14,226[a,b]	120,37±7,461[b]	0,031

[a,b] aynı satırda yer alan farklı harfler, istatiksel olarak farklılığı temsil etmektedir (*P<0,05).

Tablo2. Yumurta dış kalite özellikleri ($\bar{X} \pm S\bar{x}$)
Table 2. Egg external quality characteristics ($\bar{X} \pm S\bar{x}$)

Parametreler	Gruplar			P*
	Kontrol	Düşük kekik	Yüksek kekik	
Yumurta ağırlığı, g	9,07 ± 0,200	8,73 ± 0,591	9,77 ± 0,198	0,167
Şekil indeksi, %	84,40 ± 0,271[a]	83,08 ± 0,187[b]	82,04 ± 0,204[c]	<0,001
Kabuk ağırlığı, g	1,28 ± 0,013	1,35 ± 0,030	1,35 ± 0,028	0,148
Kabuk oranı, %	14,17 ± 0,240[a,b]	15,89 ± 0,789[a]	13,69 ± 0,436[b]	0,021

[a,b,c] aynı satırda yer alan farklı harfler, istatiksel olarak farklılığı temsil etmektedir (*P<0,05).

Tablo 3. Yumurta iç kalite özellikleri ($\bar{X} \pm S\bar{x}$)
Table 3. Egg internal quality characteristics ($\bar{X} \pm S\bar{x}$)

Parametreler	Gruplar			P
	Kontrol	Düşük kekik	Yüksek kekik	
Ak uzunluğu	41,78 ± 0,774	40,95 ± 2,607	45,73 ± 0,866	0,112
Sarı yüksekliği	8,16 ± 0,048	9,08 ± 0,889	9,10 ± 0,250	0,375
Ak yüksekliği	3,94 ± 0,133	3,87 ± 0,502	4,30 ± 0,221	0,615
Sarı genişliği	25,64 ± 1,031	28,81 ± 1,205	26,30 ± 0,307	0,525
Ak genişliği	33,16 ± 0,659	33,06 ± 1,699	32,46 ± 1,176	0,913
pH	9,02 ± 0,023[a]	8,37 ± 0,198[b]	8,84 ± 0,032[a]	0,002*
Ak ağırlığı	2,94 ± 0,138	2,99 ± 0,175	2,77 ± 0,292	0,736
Sarı ağırlığı	4,84 ± 0,051	4,38 ± 0,516	5,66 ± 0,432	0,084
Ak indeksi	10,61 ± 0,585	11,28 ± 1,740	11,04 ± 0,637	0,929
Sarı indeksi	32,24 ± 1,326	38,31 ± 4,667	34,68 ± 1,251	0,344
Haugh Birimi	88,14 ± 0,901	86,98 ± 3,760	89,44 ± 1,377	0,766
İç kalite birimi (IQU)	62,11 ± 1,827	55,54 ± 10,301	63,35 ± 2,768	0,642
Renk	4	3	2	<0,001

[a,b,c] aynı satırda yer alan farklı harfler, istatiksel olarak farklılığı temsil etmektedir (P<0,05).

Tablo 4. Diskriminant analiz modeline ait parametreler
Table 4. Parameters of discriminant analysis model

Grup	Doğruluk Oranı	Precision	Recall	F1-Score
DK	100%	1,0	1,0	1,0
K	90,9%	1,0	0,83	0,91
YK	66,7%	0,5	1,0	0,67
Genel	88,9%	0,94	0,89	0,90

Tablo5. Diskriminant Fonksiyonları İçin Katsayılar
Table5. Coefficients for Discriminant Functions

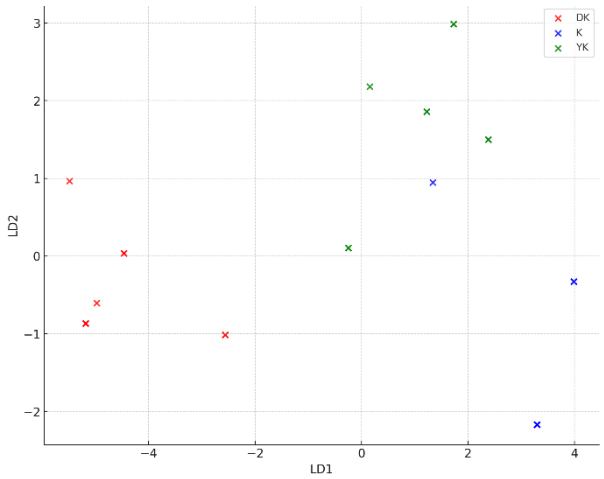
Parametre	Kontrol	Düşük kekik	Yüksek kekik
Yumurta Ağırlığı	0,9067	-0,9645	-0,1673
Yumurta eni	-0,3881	-1,4456	4,4080
Yumurta boyu	0,3303	-1,3612	2,2953
Kabuk Ağırlığı	-36,7224	46,1527	-9,7633
Yumurta Şekil İndeksi	-1,3938	1,6407	-0,1113
Sarı Rengi	-5,2871	2,2324	8,8899
Ak Uzunluğu	-0,2478	0,4401	-0,3663
Sarı Yüksekliği	-0,9456	1,2105	-0,3028
Ak Yüksekliği	1,2681	-0,5959	-1,9912
Sarı Genişliği	-0,7688	1,3250	-1,0415
Ak Genişliği	-0,5384	0,3582	0,6001
pH	0,7214	5,2001	10,2098
Ak Ağırlığı	0,8745	-1,6669	1,5573
Sarı Ağırlığı	0,6216	-0,4911	-0,5117
Ak İndeksi	0,9155	-0,2567	-1,8425
Sarı İndeksi	0,0642	0,0423	-0,2699
Kabuk Oranı	-0,5108	0,4322	0,3536
Haugh Birimi	0,236	0,356	-0,145
İç Kalite Birimi	-0,1059	-0,0849	0,4806

Modelin sınıflandırma performansı incelendiğinde, düşük kekik grubu için doğruluk oranının %100 olduğu, yani bu grubun tüm örneklerinin doğru bir şekilde sınıflandırıldığı görülmektedir. Kontrol grubu için doğruluk oranı %90,9 olarak bulunmuş olup, bu grubun büyük çoğunluğunun doğru sınıflandırıldığı anlaşılmaktadır. Sonuçlar, modelin kontrol grubunu ayırt etmede genel olarak iyi bir performans sergilediğini, ancak bazı örneklerin yanlış sınıflandırılmış olabileceğini göstermektedir. Yüksek kekik grubu için doğruluk oranı %66,7 olarak hesaplanmıştır. Bu durum, yüksek kekik grubundaki örneklerin yarısının yanlış pozitif olarak sınıflandırıldığını, ancak modelin bu grubun tüm gerçek örneklerini tespit edebildiğini göstermektedir. Genel olarak, modelin doğruluk oranı %88,9 olarak bulunmuş olup, genel precision değeri 0,94, recall değeri 0,89 ve F1-score değeri 0,90 olarak hesaplanmıştır. Bu sonuçlar, modelin genel olarak iyi bir performans sergilediğini ve gruplar arasındaki ayrımı başarılı bir şekilde gerçekleştirdiğini göstermektedir. Modelin yüksek kekik grubu için performansının iyileştirilebileceği gözlemlenmiştir; ancak, düşük kekik ve kontrol gruplarında elde edilen %100 doğruluk oranı, modelin genel dengesini ve doğruluğunu koruma gerekliliğini ortaya koymuştur. Yüksek kekik grubunda yapılacak bir iyileştirme, diğer grupların performans değerleri üzerine olumsuz etki göstereceğinden modelde herhangi bir değişiklik yapılmamıştır. Bu strateji, modelin genel sınıflandırma gücünü muhafaza etmek adına tercih edilmiştir.

Diskriminant analizinin doğruluğunu ve modelin gruplar arasındaki ayrım gücünü değerlendirmek amacıyla da çeşitli istatistiksel testler gerçekleştirilmiştir. İlk olarak, diskriminant fonksiyonlarının gruplar arasındaki varyansı ne kadar iyi açıkladığını belirlemek için eigen değerleri hesaplanmıştır. Birinci fonksiyon için eigen değeri λ_1=0,742, ikinci fonksiyon için ise λ_2=0,258 olarak bulunmuştur. Bu sonuçlar, birinci fonksiyonun gruplar arasındaki varyansın büyük bir kısmını açıkladığını göstermiştir.

Diskriminant fonksiyonlarının gruplar arasındaki ilişkiyi ne kadar iyi açıkladığını değerlendirmek için kanonik korelasyon hesaplanmıştır. Birinci fonksiyon için kanonik korelasyon değeri r_1=0,861; ikinci fonksiyon için ise r_2=0,508 olarak elde edilmiştir. Bu yüksek kanonik korelasyon değerleri, özellikle birinci fonksiyonun gruplar arasındaki ayrım gücünün oldukça güçlü olduğunu ortaya koymaktadır.

Gruplar arasındaki genel farkın açıklanmasında kullanılan Wilks' Lambda değeri ise Λ=0,191 olarak hesaplanmıştır. Düşük Wilks' Lambda değeri, modelin gruplar arasındaki farkı açıklamada etkili olduğunu göstermektedir. Son olarak, Wilks' Lambda'nın anlamlılığını test etmek için yapılan khi-kare testi sonucunda χ2=24,8 (P = 0.951, sd = 38) değeri elde edilmiştir. Bu P değeri, gruplar arasındaki farkın istatistiksel olarak anlamlı olmadığını işaret etmektedir. Bu durum, incelenen parametrelerin sayısının fazla olması, örneklem sayısının ise az olması, Khi kare önem derecesinde yüksek bir değer elde edilmesine neden olmuş olabilir şeklinde yorumlanmıştır.



Şekil 1. Diskriminant Analizi ile Grupların Ayrımı
Figure 1. Separation of Groups with Discriminant Analysis

Wilks' Lambda ve kanonik korelasyon değerleri, gruplar arasındaki ayrımın istatistiksel olarak anlamlı olduğunu ortaya koymaktadır. Bu bulgular, diskriminant fonksiyonlarının grupları doğru bir şekilde ayırt etme yeteneğini desteklemekte ve modelin genel geçerliliğini teyit etmektedir. Bu bağlamda, gruplar arasındaki farklılıkları en iyi açıklayan bağımsız değişkenlerin belirlenmesi için diskriminant fonksiyonlarının katsayıları detaylı olarak incelenmiş ve sonuçlar Tablo 5'te verilmiştir.

Diskriminant analizi sonucu elde edilen katsayılar incelendiğinde yumurta ağırlığı kontrol grubu için pozitif bir katsayıya (0,9067) sahipken, diğer gruplar için negatif katsayılar vermiştir. Bu durum, yumurta ağırlığının kontrol grubunu diğer gruplardan ayırmada önemli olduğunu göstermektedir. Kabuk ağırlığı incelendiğinde ise düşük kekik grubunun yüksek bir pozitif katsayıya (46,1527) sahip olduğu, böylece kabuk ağırlığı bakımından düşük kekik grubunun diğer gruplardan güçlü bir şekilde ayrılmasına katkıda bulunduğu belirlenmiştir. pH değeri incelendiğinde de yüksek kekik grubunda yüksek bir pozitif katsayı (10,2098) elde edilmiş ve pH değerinin yüksek kekik grubunu diğer gruplardan ayırmada önemli bir rol oynadığı sonucuna varılmıştır. Yüksek kekik grubu için yüksek bir pozitif katsayı (8,8899) sarı renginin bu grup için önemli olduğunu, düşük kekik ve kontrol gruplarında ise sarı renginin bu ayrımda negatif yönde katkı yaptığını göstermiştir. Diğer parametrelerin katsayıları, grupların ayrılmasına daha az katkıda bulunmuş, ancak yine de belirli grupların farklılaşmasında rol oynamıştır. Örneğin, sarı yüksekliği ve ak yüksekliği gibi parametreler, bazı gruplar için ayrım sağlarken, diğer gruplar için ayrımda etkisi daha az olmuştur.

Diskriminant analizinde, LD1 ve LD2 eksenleri, gruplar arasındaki varyansı en iyi açıklayan doğrusal kombinasyonları temsil etmekte olup, analiz sonucu elde edilen sonuçlar Şekil 1'de verilmiştir.

Grafikte, yumurta kalite parametrelerinin diskriminant analizi sonucu gruplar arasındaki ayrımını gösteren bir dağılım bulunmaktadır. LD1 gruplar arasındaki en büyük varyansı açıklayan fonksiyon olarak tanımlanmıştır. Düşük kekik grubu LD1 boyunca diğer gruplardan belirgin bir şekilde ayrılmıştır. Bu ayrım, düşük kekik grubunun özellikle kabuk ağırlığı ve pH gibi parametrelerle diğer gruplardan farklılaştığını göstermektedir. LD2, gruplar arasındaki daha ince farklılıkları açıklamak üzere tanımlanmıştır ve yüksek kekik grubu ve kontrol grubu arasında LD2 fonksiyonuna dayalı bir ayrım görülmektedir. Yüksek kekik grubunun LD2 üzerinde daha yüksek değerler aldığı, dolayısıyla bu grubun farklı parametre değerleri ile diğer gruplardan ayrıldığı anlaşılmaktadır. Düşük kekik grubu, negatif LD1 değerleri ile sağa doğru belirgin bir şekilde ayrılırken, kontrol ve yüksek kekik grupları pozitif LD1 değerleri ile ayrılmıştır.

Tartışma

Bu çalışmada, bıldırcın yemlerine farklı oranlarda kekik yağı eklenmesinin yumurta kalite parametreleri üzerindeki etkileri değerlendirilmiştir. Değerlendirmede elde edilen veriler iki farklı analizle incelenmiş ve sonuçlar iki analiz birlikte yorumlanarak değerlendirilmiştir.

ANOVA, incelenen parametrelerden yumurta kabuk oranı, yumurta ağırlığı ve sarı renginin gruplar arasında anlamlı farklılıklar sergilediğini göstermiştir. Ancak, ANOVA'nın sınırlı bir analiz kapasitesi bulunmakta olup, yalnızca bağımsız değişkenlerin gruplar üzerindeki etkisini tek tek değerlendirmesi nedeniyle çoklu değişkenlerin birlikte nasıl çalıştığını ve gruplar arasındaki ince farkları yakalamada yetersiz kalmasına neden olabilmektedir. Diskriminant analizi ise, gruplar arasındaki ayrımı sağlayan en etkili değişkenleri belirleyerek, bu değişkenlerin birlikte nasıl çalıştığını ortaya koymaktadır. Örneğin, kabuk ağırlığı, pH ve sarı rengi gibi parametreler, diskriminant analizinde gruplar arasındaki ayrımda kritik rol oynamış, bu parametreler grupların doğru sınıflandırılmasını sağlamıştır. ANOVA'da anlamlı bulunmayan bazı parametrelerin, diskriminant analizinde gruplar arasındaki ayrımı belirleyen önemli faktörler olduğu tespit edilmiştir. Bu da diskriminant analizinin gruplar arasındaki ince farkları yakalamada daha güçlü olduğunu göstermektedir (Abdel-Wareth, 2016).

Literatürle karşılaştırıldığında, çalışma bulguları genel olarak benzer sonuçlar ortaya koymaktadır. Yapılan çalışmalarda, kekik ekstraktının yumurta kabuk kalitesi üzerinde hem pozitif hem de negatif etkiler yaratabileceği belirtilmektedir. Botsoglou ve ark. (2003), 5 g/kg kekik esansiyel yağı ilavesinin yumurta şekil indeksi, yumurta kabuk kalınlığı veya Haugh birimini etkilemediğini göstermiştir. Florou-Paneri ve ark. (2005), yumurtacı tavukların rasyonlarına 50 ve 100 mg/kg kekik esansiyel yağı ilavesinin yumurta kabuğu mukavemeti, yumurta şekil indeksi, yumurta kabuğu kalınlığı ve kabuk oranı üzerinde herhangi bir değişikliğe neden olmadığını bildirmiştir. Mevcut sonuçlar, şekil indeksi ve kabuk oranı haricindeki durumlarda bu bulguları desteklemektedir. Radwan Nadia ve ark. (2008), tarafından yapılan bir çalışmada ise, 5 ve 10 g/kg kekik esansiyel yağı ilavesinin yumurta kabuk ağırlığı ve yumurta şekil indeksi üzerinde herhangi bir etkisi bulunmamış; benzer şekilde, tavuklarda yapılan başka bir çalışmada ise yumurta kalite parametrelerinin, farklı oranlarda bitkisel yağ içeren gruplar arasında herhangi bir farklılık meydana getirmediği; sadece yumurta kabuğunda bir kalınlaşma görüldüğü bildirilmiştir (Ding ve ark., 2017). Benzer şekilde, Gül ve ark. (2019), çalışmalarında rasyona farklı oranlarda kekik yağı ilavesinin yumurta kalite

parametrelerinde herhangi bir değişikliğe neden olmadığını ancak kabuk ağırlığında gruplar arasında istatiksel olarak farklılık gözlendiğini bildirmiştir. Ayrıca, Xiao ve ark. (2022), çalışmasında bitkisel yağların kabuk kırılma direncini artırabileceği, ancak yüksek dozlarda olumsuz etkiler gösterebildiğini açıklamıştırr. Darmawan ve ark. (2022), phytogenik ekstraktların yumurta ağırlığı gibi parametreler üzerinde genel olarak olumlu etkiler yaratmadığını, ancak yumurta verimliliği ve kabuk kalitesi üzerinde belirgin iyileştirmeler sağladığını belirtmiştir. Esenbuga ve Ekinci (2023), tarafından yapılan çalışmada, kekik yağının kabuk kalitesi üzerindeki etkilerinin doza bağlı olarak değiştiği ve yüksek dozların olumsuz sonuçlar doğurabileceği belirtilmiştir. Orzuna-Orzuna ve Lara-Bueno (2023), yumurta dış kalite parametrelerinin bitkisel yağ katkısı ile artış gösterdiğini kaydetmiştir. Çalışmada, kabuk oranı bakımından gruplar arasında istatistiksel olarak anlamlı farklılıklar tespit edilmiştir. Özellikle düşük kekik grubunda kabuk oranı en yüksek bulunurken, yüksek kekik grubunda bu oran önemli ölçüde düşmüştür. Bu durum, kekik gibi bitkisel katkı maddelerinin yüksek dozlarda kabuk kalitesini olumsuz etki gösterebileceği bulguları ile örtüşmektedir. Benzer şekilde, incelenen çalışmaların büyük oranda farklı bir tür olan yumurtacı tavuklarda yapılmış olması ve farklı dozlarda kekik ilavelerinin veya diğer bitkisel ekstraktların kullanılmış olması, yumurta dış kalite parametrelerinin bazılarında farklı sonuçlar elde edilmesine neden olarak düşünülmüş ancak bulgular ile örtüşme sağlanmıştır.

Bıldırcın rasyonlarına kekik yağı ilavesinin yumurta iç kalite parametrelerine etkisi incelendiğinde ise mevcut çalışmada iç kalite parametrelerinden sadece pH bakımından gruplar arası farklılık tespit edilirken, diğer parametrelerde sadece rakamsal farklılıklar gözlenmiştir. Bu parametrelerin diskriminanat analizi ile incelenmesinde ise Haugh biriminin gruplar içerisinde farklılıklar sergilediği görülmüştür. Çalışma bulgularından farklı olarak, Botsoglou ve ark. (2003), 5 g/kg kekik esansiyel yağı ilavesinin Haugh birimini etkilemediğini göstermiştir. Benzer şekilde, Florou-Paneri ve ark. (2005), yumurtacı tavukların rasyonlarına 50 ve 100 mg/kg kekik esansiyel yağı ilavesinin Albumin indeksi ve Haugh Birimi üzerinde herhangi bir değişikliğe neden olmadığını bildirmiştir. Radwan Nadia ve ark. (2008), tarafından yapılan bir çalışmada da 5 ve 10 g/kg kekik esansiyel yağı ilavesinin ak indeksi, sarı indeksi veya Haugh birimi üzerinde herhangi bir etkisi bulunmamıştır. Ancak, Esenbuga ve Ekinci (2023), kekik ekstraktının, yumurta iç kalite parametreleri üzerinde belirgin etkileri olduğunu bildirmiştir. Orzuna-Orzuna ve Lara-Bueno (2023), yumurta iç kalite parametrelerinden ak yüksekliği Haugh birimi ve sarı indeksinin bitkisel yağ katkısı ile artış gösterdiğini kaydetmiştir. Mevcut çalışmada ise DK grubunda pH değerinde gözlemlenen anlamlı düşüş, kekik ilavesinin yumurta iç kalite parametreleri üzerindeki etkilerine dair önemli bir bulgu olarak değerlendirilmiştir. Bu durum, kekik ilavesinin yumurta iç pH değerini optimize etmek için potansiyel bir strateji olarak kullanılabileceğini göstermektedir.

Çalışmada, bıldırcın yemlerine kekik yağı ilavesinin yumurta sarısı renginde Roche renk skalasına göre farklılıklar gösterdiği tespit edilmiştir. Gül ve ark. (2019), çalışmalarında rasyona farklı oranlarda kekik yağı ilavesinin sarı renginde gruplar arasında istatiksel olarak farklılık gözlendiği bildirmiştir. Esenbuga ve Ekinci (2023), çalışmalarında, sarı renginde açılmalar oluştuğu belirtmişlerdir. Orzuna-Orzuna ve Lara-Bueno (2023), kekik yağının sarı rengi üzerinde olumsuz etkiler yaratabileceğini bildirmişlerdir. Bulgular çalışma sonuçları ile benzerlik göstermiş; yumurta sarı renginde YK grubunun daha açık bir renk sergilediği tespit edilmiştir. Ancak Gül ve ark. (2019), yukarıda belirtilen çalışmasında yumurta sarı renginin bitkisel yağ katkısı ile arttığı bildirilmekte olup, bu bulgu diğer çalışmalardan farklı bir sonuç olarak değerlendirilmiştir. Yumurta sarısı rengi, genellikle yemle alınan karotenoidlerden etkilenmekte ve bu bileşiklerin biyoyararlanımıyla ilişkilendirilmektedir. Kekik yağı gibi bitkisel ekstraktlar, antioksidan özellikleriyle bilinir. Bu özellikler, yem kaynaklı karotenoidlerin oksidasyonunu önleyebilir veya azaltabilir. Bununla birlikte, bazı durumlarda, bu antioksidan etkiler karotenoidlerin biyoyararlanımını etkileyebilir ve bu da yumurta sarısının daha açık renkli olmasına neden olabilir. Ayrıca, rasyona eklenen kekik yağı, karotenoidlerin biyoyararlanımını azaltabilir veya diyetin diğer bileşenleriyle etkileşime girerek yumurta sarısı renginde açılmaya neden olabilir. Kekik yağının kendisi karotenoid içermediğinden, sarı rengini doğrudan koyulaştırması beklenmez. Aksine, kekik yağının, yukarıda belirtildiği gibi, yemle alınan karotenoidlerin metabolik kullanılabilirliğini etkileyerek sarı renginde açılmalara neden olabileceği öne sürülmektedir. Özellikle yüksek dozlarda kekik yağı kullanımı, sarı renginin açılmasına yol açabilir, çünkü bu bitkisel yağın antioksidan etkisi, karotenoidlerin oksidasyonunu engelleyerek, pigmentlerin sarıya dönüşümünü azaltabilir. Ayrıca, yapılan bir meta-analiz, bitkisel yağların yumurta kalitesi üzerinde genel olarak pozitif etkiler yaratmasına rağmen, bu yağların yumurta sarısı renginde belirgin bir açılma eğilimi gösterebileceğini belirtmektedir (Bozkurt ve ark., 2014; Faitarone ve ark., 2016).

Bu sonuçlar, kekik ilavesinin, özellikle belirli dozajlarda, yumurta iç kalite parametreleri üzerinde sınırlı bir etkisinin olduğunu göstermektedir.

Sonuç

Sonuç olarak, çalışmada elde edilen bulgular, mevcut literatürle büyük ölçüde uyum göstermiştir. Kekik gibi bitkisel katkı maddelerinin, kanatlı yemlerinde kullanımı uzun süredir araştırılmaktadır. Bitkisel katkıların, sindirim sağlığını iyileştirici, antimikrobiyal ve antioksidan özellikleri sayesinde genel olarak yumurta kalitesini artırabileceği bilinmektedir. Ancak, yüksek dozlarda bu katkıların bazı istenmeyen etkilere yol açabileceği literatürde de vurgulanmaktadır. Özellikle, bitkisel katkıların optimal düzeyde kullanılması gerektiği, aksi takdirde yumurta kalite parametrelerinde olumsuz değişikliklere neden olabileceği belirtilmektedir. Diskriminant analizi, bıldırcın grupları arasında belirgin ayrımlar olduğunu ve bu ayrımların hangi değişkenler tarafından sağlandığını göstermiştir. Analiz sonuçları, ANOVA sonuçlarına ek olarak, gruplar arasındaki farkları daha ayrıntılı bir şekilde ortaya koymuştur. Bu farklar, örneğin Haugh Birimi ve kabuk ağırlığı gibi değişkenler üzerinden grupların nasıl ayırt edilebileceğini

göstermektedir. Kekik yağının yüksek dozlarda kullanılmasının yumurta kalite parametreleri üzerine olumsuz etki de gösterebileceği literatür ile desteklenmiş; ancak olumlu sonuçlar verdiği de göz önüne alınarak, en uygun dozun belirlenmesine yönelik çalışmaların sürdürülmesi gerekli görülmüştür.

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Şevket Evci: Proje yönetimi, gözetim, kavramsallaştırma, metodoloji, inceleme ve düzenleme

Erva Eser: Veri toplama, araştırma, kavramsallaştırma, metodoloji, resmi analiz ve orijinal taslağın yazılması

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Effects of Adoption of Agricultural Technologies on Irish Potato Yield in Ol Kalou Sub-County Kenya: Application of Endogenous Switching Regression Model

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Yield

ABSTRACT

Population growth has increased demand and diversified use of Irish potato which have increased its demand. The crop has become a major source of food and income for many households across the world. However, despite the high potential of about 30 tonnes per hectare (ha), smallholder farmers in Kenya realize low Irish potato yields ranging from 4-8 tonnes per ha due to limited uptake of agricultural technologies. The low yields calls for a profound understanding of the factors influencing the uptake agricultural technologies. The study analyzed the effects of the adoption of agricultural technologies on Irish potato yield in Ol Kalou Sub County. The study considered chemical fertilizer, certified seeds, fungicides, and farm machinery as the four main agricultural technologies that that affect yield. A descriptive cross-sectional research design was used to obtain data from a study population of 21,942 smallholder Irish potato farmers in Ol Kalou Sub County. A multiple-stage sampling technique was employed to generate a sample size of 385 respondents who provided primary data. Data collected was analyzed using endogenous switching regression model using STATA version 17. The study found that the average treatment effect on treated (ATT) was 10.21 bags per acre. In addition, the Endogenous switching regression model showed that the expected yield for the adopter increased by 51.83%. Out of the four technologies, the use of chemical fertilizers had the highest effect of 37% on yield. The study concluded that the adoption of agricultural technologies increases the yield of Irish potatoes. The study recommends that national and county governments should develop policy regulations such as training and extension services, market access, price support and public-private partnerships encouraging farmers to uptake agricultural technologies. The study also recommends that both levels of government should subsidize agricultural technologies, hence reducing the cost of adoption.

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Introduction

Irish potato is an essential food crop recommended by the United Nations as a vital food security crop produced in over 100 countries globally (Djaman et al., 2021). Irish potato originated from Ireland, thereby gaining the term "Irish", and later spread to other parts of the world during the movements of the Britons (Hassan et al., 2020). Potato is a primary food crop produced in the majority of developing countries. It is the fourth most-produced food crop globally at about 314 after corn at 822, wheat at 689 and rice at 685 million metric tonnes (Wang et al., 2020). In most parts of the world, especially Africa, Asia, Europe, and Southern and Northern America, Irish potato production is a fundamental economic activity both for small-scale and large-scale farmers who aim at increasing food security (Thuo & Maina, 2024). The Irish potato produced in the world does not meet the global demand, which calls for improvement in production technologies (Karashchuk & Fedonenko, 2020).

The global Irish potato production is over 300 million metric tonnes annually, and over one billion people consume potato globally (Setiawan & Inayati, 2020. The high number of individuals consuming potato shows the importance of the crop to most households in different parts of the globe. Before the 1990s, the major potato producers and consumers were North America, Europe, and most members of the Soviet Union (Muriithi et al., 2020). Since 2017, there has been a drastic increase in potato demand in developing countries, including Latin

America, Africa, and Asia, which requires producers to improve their production practices (Richards & Rickard, 2020). China's production surpasses that of any other country globally, and approximately a third of the world's production is done in China and India, with the production of about 22 percent Irish potato produced annually in the world (Wang et al., 2020).

In most of the countries in the world where agrarian transformation has occurred, improvement in Irish potato productivity has been facilitated by improved technologies such as fertilizers, clean seeds, use of machineries and fungicides (Evelyne et al., 2021; Muriithi et al., 2020; Setiawan & Inayati, 2020). Since 2010, there has been an increase in potato production in China and India, which can be attributed to the adoption of irrigation technology among potato farmers especially regions that did not grow potato previously (Muriithi et al., 2020). The increase in potato production could also be attributed to population growth and the need for food (Evelyne et al., 2021). Lack of application of technology in agricultural production results in low agricultural yields (Akoto et al., 2020 and Wei & Lu, 2024).

The average Irish potato production in Africa is about 14.2 tonnes per hectare (ha) (Djaman et al., 2022). There is a significant gap in the production other continents, such as America, producing 25.9 tonnes per ha, Europe at 21.1 tonnes per ha, and Asia at 18.3 tonnes per Ha (Barasa, 2019). The difference in Irish potato production between Africa and other countries is attributed to differences in the application of agricultural technologies (Evelyne et al., 2021). Despite Africa lagging behind, FAO statistics showed that potato production has tripled from 8 to 24 million metric tonnes from 1994 through 2011, which is attributed to increased cropping area and the application of agricultural technology (Hossain, 2016). A study by Richards & Rickard (2020) established that the current level of Irish potato production could rise by 140 percent if farmers embrace application of the available technology. Fitz-Koch et al. (2018) alluded that entrepreneurs in sub-Saharan Africa have established that the uptake of agricultural technologies is key in increasing the yield of different crops, including the Irish potato.

In Kenya, just as in other parts of the world, Irish potato demand has risen in the past decade due to increasing urbanization, where it is ranked second among town dwellers consumers (Thuo & Maina, 2024). Kenya has a potential yield of between 4 and 8 tonnes per hectare compared to a world potentiality of 30 tonnes per hectare (Evelyne et al., 2021). Barasa (2019)) reported that Kenya's acreage of Irish potato production is gradually reducing from 192,341 hectares in 2007 to about 109,614 hectares in 2017, which is associated with land fragmentation. If the farmers are to overcome the decline in Irish potato production, the uptake of advanced practices would increase ease and efficiency at the farm level and in marketing. Kenya has a high potential for potato production, which has remained underutilized for many years due to the lack of uptake of agricultural technologies in different parts of the country (Barasa, 2019). The Kenyan government has come up with structures in agricultural research that are geared toward enabling the agriculture sector to be responsive to low production (Thuo & Maina, 2024).

Adoption of agricultural technology has resulted in increased yield among adopters (Far & Rezaei-Moghaddam, 2018), Donkoh et al., 2019), and Shita et al., 2020). The uptake of innovations in the agricultural sector has been a game-changer in both yield and income for the farmers (Shita et al., 2020). There is a significant difference in yield between the non-adopters and adopters of agricultural technologies (Donkoh et al., 2019. There have been intense studies in developed countries about the impact of the adoption of agricultural technologies on yield and income; Therefore, there is a need to establish the effect adoption of agricultural technologies in Ol Kalou. Ol Kalou Sub County lies in Nyandarua County, which is a top potato producer, contributing approximately 33% of total potato production in Kenya, which is below its potential (Muriithi et al., 2020). Mwangi et al. (2015) argued that the sector supports the potato value chain directly or indirectly with over 131,697 farm families. Despite, Irish potato being the second most-produced agricultural product in the County, after dairy, there is low adoption of agricultural technologies (Nyagaka et al., 2010). Irish potato production in Ol Kalou is, on average, 4-8 tonnes per hectare, which is below the average potentiality of about 30 tonnes per hectare produced in developed countries (Mumia et al., 2018). There is a need to establish the influence of the adoption of agricultural technologies on yield.

Materials and Methods

Study Area

The study was carried out in all five wards of Ol Kalou Sub County in Nyandarua County in June and October 2022. The five wards include Kaimbaga, Ruria, Karau, Kanjuire Ridge and Mirangine, which covers a total area of 384.9 km^2 and has a population of 75,262 (County Government of Nyandarua, 2018). The area was selected because it had was among high Irish potato producers in Kenya where government had invested in agricultural technologies in the past 10 (Mumia et al., 2018). Ol Kalou is located on the west slopes of the Aberdare Ranges, and it is one of the five sub-counties of Nyandarua County. The majority of the land in Ol Kalou Sub County is arable due to the fertile soils in the area (Mumia et al., 2018).

Research Design

The study applied a descriptive cross-sectional research design. The research design described the state of adoption of agricultural technologies among Irish potato farmers. Blazy et al. (2009) stated that a descriptive cross-sectional research design is one of the approaches that utilize and gain an accurate profile of effects of adoption of agricultural technologies on yield. The use of descriptive research design catered for the collection of mixed techniques involving qualitative and quantitative data. Finally, the design was useful in the determination of the impacts of the adoption of agricultural technologies on yield.

Target Population and Sample Size

The study targets smallholder Irish potato farmers in Ol Kalou sob-county. The total study population was 21942 (County Government of Nyandarua, 2018) households practicing Irish potato production in Ol Kalou Sub County. The major qualification for one to qualify to be a respondent is that they must be a smallholder Irish potato

producer. Additionally, one had to be an Irish potato farmer continuously for the past five years from 2018 to 2022. The continuous ensured that there were no new entrants in Irish potato production since they may lack adequate knowledge about the available agricultural technologies and their impact on yield. A sample size of 385 was obtained using Cochran formula and multiple stage sampling technique was applied to select the respondents.

Data Collection

The study adopted the use of primary data, which was collected through a structured questionnaire that captured various variables of the study. The questionnaire was installed in Open Data Kit (ODK) and later downloaded in SPSS. The questionnaires were administered with the assistance of enumerators who understand the local language. In addition, data on effect of adoption of agricultural technology on yield and income of smallholder Irish potato was collected in two Irish potato seasons namely June-August and August-October, 2022. The production schedule administered by the five enumerators were to record the total output for adopters and non-adopters.

Data Analysis

The primary data collected was first checked and sorted for consistency and completeness before analysis. Checking and sorting were done with the aim of making sure all elements of the questionnaire were answered. The study used descriptive statistics like frequencies and percentages to present and summarize data collected from smallholder Irish potato producers in Ol Kalou Sub County. The study also employed Pearson correlation analysis to establish any significant association between different study variables. The study applied independent sample test to establish the yield difference between the adopters and non-adopters of agricultural technologies. Endogenous Switching Regression (ESR) was used to determine the impact of yields.

Endogenous Switching Regression Model

The Irish potato farmer's decision to uptake a given technology was under the condition of the different variables. A farmer expects to maximize yield which is their utility function subject to different variables that forms the constraints. The use of the ESR model to analyze the potential yield for non-adopters and adopters of agricultural technologies was justified since the model accounted for bias associated with unobserved variables.

$$\mathrm{R} = \mathrm{W_A} - \mathrm{W_{NA}} > 0 \qquad (1)$$

where R represents the dummy observed variable that is 0 for the non-adopters and 1 for adopters of agricultural technology. W represents the benefits a farmer obtains from the adoption of agricultural technologies, such as crop productivity, increased income and food security. The subscripts (A) denote the adopters of technologies, and (NA) is for non-adopters of agricultural technologies, respectively. The extent of adoption of agricultural technologies can be specified as follows;

$$\log R_i = \max(0, R_i^*) + \beta' X'_{\mathrm{i}} + Ui \qquad (2)$$

The ESR model involved two stages. The model started by adoption behaviour using the constrain variable. The first step was followed by estimation of productivity discretely for non-adopters and adopters of combined technologies conditional on their decision to uptake agricultural technologies. Therefore, an ordered probit model was utilized to model the adoption behaviour of Irish potato farmers, and separate regression models were used to model the production function conditional to the specified criterion function.

The decision of a farmer to uptake a given technology can be modelled in a utility maximization framework (Läpple & Kelley, 2013). Utilities difference between the adopters U_{Ai} and the non-adopters U_{Ni} of agricultural technologies (AGs) of Irish potato was denoted as G^* such that the i^{th} farmer was likely to adopt given technologies if U_{Ai} was greater than $U_{Ni.}$ That is, a farmer would adopt a bundle of AGs when $G^* = U_{Ai} - U_{Ni} > 0$. G^* was unobservable and hence the study expressed it as a function of observable issues in the latent variable (probit model) as follows:

$$G^*_1 = \beta X_i + ui \text{ where } G_1 = \begin{cases} 1 \text{if } G^*_1 > 0 \\ 0 \text{ if } G^*_1 \leq 0 \end{cases} \qquad (3)$$

where G is dichotomous taking value of 0 for non-adopters and 1 for adopters of agricultural technologies on Irish production, X is the vector of independent variables; β is the vector of unknown constraints while u is the stochastics random term with mean and variance σ^2 of 0. The maximum likelihood estimation procedure was applied to determine the vector of probit coefficients β.

$$Y_{1i} = \alpha_1 J_{1i} + \epsilon_{1i}, \text{if } G_1 : 1 \qquad (4)$$

$$Y_{0i} = \alpha_0 J_{0i} + \epsilon_{0i}, \text{if } G_1 : 0 \qquad (5)$$

Y_1 and Y_0 represent Irish potato yield with agricultural technologies and without agricultural technologies, respectively. For a given Irish potato farmer, Y_1 or Y_0 were observed based on the values of criterion function in equation (2). The model made an assumption that the error terms had a trivariate normal distribution with non-singular covariance matrix and mean of 0 as expressed below;

$$COV(\epsilon_{1i}\epsilon_{0i}, u_i\epsilon) = \begin{pmatrix} {\sigma^2}_{\epsilon 1} & \sigma_{\epsilon 1 e 0} & \sigma_{\epsilon 1 u} \\ \sigma_{\epsilon 1 e 0} & {\sigma^2}_{\epsilon 0} & \sigma_{\epsilon 0 u} \\ \sigma_{\epsilon 1 u} & \sigma_{\epsilon 0 u} & {\sigma^2}_{u} \end{pmatrix} \qquad (6)$$

where the ${\sigma^2}_u$ represent variance of the error in the criterion equation (6) ${\sigma^2}_{\epsilon 1}$ and ${\sigma^2}_{\epsilon 0}$ are the variances of the errors α_1e1 and e0in the yield outcome function in eq 1 are the covariances respectively of the error terms u , ϵ_1, and ϵ_0. The outcome functions equations were not observed concurrently as expressed by equations 6 and 7:

$$E|\epsilon 1i|\, G_i = \sigma_{\epsilon 1 u} \frac{\phi(\beta X_i/\sigma)}{\Phi(\beta X_i/\sigma)} = \sigma_{\epsilon 1 u} \lambda_{1i} \qquad (7)$$

$$E|\epsilon 0i|\, G_i = -\sigma_{\epsilon 0 u} \frac{\phi(\beta X_1/\sigma)}{1-\Phi(\beta X_i/\sigma)} = \sigma_{\epsilon 0 u} \lambda_{0i} \,. \qquad (8)$$

where;
ϕ -is the standard normal probability density function
Φ-is standard normal cumulative density function
λ_{1i} and λ_{0i} Estimated ratio evaluated at βX_i

The study also used full information maximum likelihood (FIML) to estimate the endogenous switching regression model. The FIML estimated concurrently the conditional equation (probit model) and the yield functions to give standard errors that were reliable. The equation was given as:

$$Ln\ L = \sum_{i=1}^{n} G_i \left(ln\phi \left(\frac{\epsilon 1i}{\sigma_{\epsilon 1}} \right) - ln\sigma_{\epsilon 1} + ln\Phi(\phi_{1i}) \right) + (1 - G_i) \left(ln\phi \left(\frac{\epsilon 0i}{1\sigma_{\epsilon 0}} \right) - ln\sigma_{\epsilon 1} + \ln\left(1 - \Phi(\phi_{1i})\right) \right) \quad (9)$$

The study assumed that production, financial and marketing factors had differential effects on productivity where separate yield outcome functions for adopters and non-adopters had to be specified, while at the same time accounting for endogeneity. Therefore, the econometric problem involved sample selection and endogeneity.

Results

Level of Adoption

The study sought to categorize the farmers into either adopters or non-adopters of agricultural technologies in the Ol Kalou sub-county. It was found that that majority (52.20%) were adopters of agricultural technologies while 47.80% were non-adopters in production of Irish potato (Table 1).

Difference in Yield Between Adopters and Non-Adopters

The study sought to determine whether there was a significant difference between the adopters and non-adopters of agricultural technologies on Irish potato yield. Independent samples *t*-test was used to establish whether there was a difference in yields between adopters and non-adopters. The equality of variances test showed an F value of 43.09 and a significant value of 0.00, indicating that there was significant variability in yield between the adopters and non-adopters (Table 2). The study findings showed a significant difference in yield obtained from Irish potato production between adopters and non-adopters, with a *t*-value of 5.32 and a p-value of 0.00 (Table 2).

The study findings showed that there is a difference in farm productivity per acre between the adopters and non-adopters of agricultural technologies (Table 2). The findings of this study suggest that adoption of different agricultural technologies among Irish potato farmers had a measurable impact on yield. Additionally, the findings of the study implied that the use of agricultural technologies in the Irish potato sub-sector was likely to contribute to changes in yield per acre. The study findings are consistent with those of Shita et al. (2020), who found a significant difference in crop production between the adopters and non-adopters of agricultural technologies. However, further analysis was done using the ESR model to establish which group had more output.

Estimation of Yields Using the Endogenous Switching Regression Model

The study sought to determine the impact of the adoption of agricultural technologies on yields using the endogenous switching regression model (ESR). The ESR model was used to compare the expected yield of adopters and non-adopters of agricultural technologies. The study compared the yield of the actual situation (adopters if they do not adopt) and the counterfactual condition (yield of a farmer without technologies if they adopt). To determine if there was a significant effect upon adoption of agricultural technologies on yield, the following hypothesis was formulated;

H_0: There is no statistically significant effect of the adoption of agricultural technology on the yield of smallholder Irish potato farmers in Ol Kalou Sub County.

The findings indicated that the expected yield of the farmer who adopted agricultural technologies was 40.22 bags per acre, while the expected yield of the farmer who did not adopt was 30.01 bags per acre under the counterfactual condition (Table 3). The findings of the study found that the average treatment effect on treated (ATT) was 10.21 bags per acre (p=0.01<0.05), indicating that adopters of agricultural technologies had a possibility of decreasing their expected yield by 25.39% per acre (Table 3) if they failed to adopt the technology.

Table 1. Adopters and Non-adopters of agricultural Technologies.

Level of Adoption	Frequency	Percent
Adopters	201	52.20
Non-Adopters	184	47.80

Table 2. Independent Samples *t*-Test for Output Variation

Variable	Category	F	Sig	t	Df	Sig (2-tailed)
Output	Equal Variances Assumed	43.09	0.00	5.21	383	0.00
	Equal Variances not Assumed			5.32	332.79	0.00

Note: *** significant at 1% level, ** significant at 5% level, *significant at 10% level

Table 3. Average Treatment Effect of Treated and Average Treatment Effect of Untreated the in Irish Potato Yield

Outcome	Mean Outcome		ATT	ATU	Effect (%)
	Adopters	Non-Adopters			
Total Yield (bags/acre)	40.22(0.02)	30.01(0.02)	10.21**(0.01)		25.39
	42.02(0.06)	20.24(0.05)		21.78**(0.01)	51.83

Note: *** significant at 1% level, ** significant at 5% level, *significant at 10% level

Table 4. Effects of Different Agricultural Technologies on Yield of Farmers: Estimates by ESR Model

Category		Mean Outcome		ATT	ATU
		Adopters	Non-Adopters		
Fertilizer	Yes	3.69(0.05)	3.33(0.05)	0.37**(0.03)	
	No	5.28(0.04)	3.40(0.03)		1.88**(0.03)
Certified Seeds	Yes	4.02(0.06)	3.65(0.05)	0.35***(0.03)	
	No	5.78(0.02)	3.94(0.02)		1.84***(0.02)
Fungicides	Yes	3.49(0.07)	3.20(0.06)	0.29*(0.04)	
	No	4.08(0.06)	3.05(0.05)		1.03*(0.03)
Farm Machinery	Yes	4.13(0.05)	3.81(0.05)	0.32*(0.03)	
	No	4.09(0.06)	3.75(0.05)		0.34*(0.03)

Note: *** significant at 1% level, ** significant at 5% level, *significant at 10% level

Furthermore, the findings of this study showed that if the farmers do not actually adopt agricultural technologies, the average treatment effect on untreated (ATU) was 21.78 bags per acre (p=0.01<0.05), implying that the expected yields increased by 51.83% per acre (Table 3).

Effect of Agricultural Technologies on Yield

The study also sought to establish whether the four technologies (use of chemical, certified seeds, farm machinery and fungicides) under investigation had differences in the impact of the yield of Irish potato. The findings of the study indicated that use of chemical fertilizer technology had the highest impact on the yield indicating a 37.00% increase for adopters of Irish potato at a 5% significant level. The outcomes of the study indicated that the application of certified seeds had the second-highest yield-increasing effect of 35.00% at a 1% statistical level (Table 4).

The adoption of farm machinery was significant at a 10% statistical level. The uptake of farm machinery had the third highest effect on yield at 32.00%. The adoption of fungicides had the least impact, indicating that the adoption increased yield by 29.00%. The adoption of fungicides had a positive and significant impact at 10% statistical level (Table 4).

Discussion

The difference between the actual yields and the counterfactual condition yields reflected the average treatment effect associated with the adoption of agricultural technologies (yield increasing effect brought by the application of agricultural technologies) [Table 3]. The study also found that the farmers who did not actually uptake agricultural technologies had a more significant yield increase if they adopted more agricultural innovations shown by ATU>ATT. The finding suggests that the uptake of agricultural technologies in Irish potato production improves farm-level productivity. Therefore, these findings do not support the null hypothesis that there is no statistically significant effect of adoption of agricultural technology on yield of smallholder Irish potato. The findings from this study may also indicate that the farmers who do not uptake the available technologies are likely to reduce their output due to the dynamic nature of the agricultural sector that is characterized by seasonality, infestation from pests and diseases and loss of soil fertility (Table 3). The findings of this study are in agreement with those of Wu (2022) and Fuglie & Echeverria (2024), who found that the adoption of agricultural technology has an impact on increasing output.

The findings imply that applying chemical fertilizers provides crop nutrients and encourages vegetative growth, which renews soil organic matter, which is essential in increasing yields (Table 4). In addition, the application of chemical fertilizer technology, especially if it is a biofertilizer, may improve soil biological activities and promote its properties, hence increasing soil fertility. The findings of this study concur with those of Tilahun et al. (2022), and Haris et al. (2023), who found that the usage of chemical fertilizer technology forms a source of essential plant nutrients, which increases crop yield. Further, the findings of this study are in agreement with those presented by Wu (2022), who postulated that the application of chemical fertilizer technology ensures soil fertility that assists in increasing crop yields.

The findings of the study imply that the adoption of certified seeds can increase a farmer's productivity per unit area. Additionally, the use of certified seeds is associated with a reduction in incidences of transfer of insect pests and diseases from one farm to another or from one season to another, which may increase the yield. The findings of the study are in consonance with those of Fuglie & Echeverria (2024), who established that the use of certified seed increases yield compared to the where the farmers recycle the seed. Similar findings are presented by Zilberman et al. (2018), who established that usage of certified seeds improves yields since the seeds are resistant to pests and tolerant to herbicides and drought.

The findings indicated that the adoption of farm machinery could promote farm productivity, hence increasing yields (Table 4). The findings of this study may also show that the adoption of farm machinery can save agricultural labour and increase the area in which a farmer operates, thereby increasing yields. The adoption of farm machinery technology may imply that farmers increase efficiency and assist in growing more crops in less time. The findings of this study agree with those of Wei & Lu (2024), who established that adopting farm machinery reduces the farmer's labour input cost, allowing them to concentrate on improving productivity. The outcomes of this study are in consonance with Liao et al. (2022), who postulated that the adoption of farm machinery reduces labour costs and increases the yields per unit area. However, the findings of the study are against the one presented by Mohammed et al. (2023), who found that the adoption of farm machinery technology had the least impact on yield and income, which was associated with limited usage and a low degree of mechanization among farmers.

The findings imply that the adoption of the fungicide technology could have been higher in the study area, although their usage did not affect the final yield. The study findings are against Kassaw et al. (2021), who established that the impact of fungicide technology among Irish potato farmers had immense benefits on yield due to the presence of late and early blight. On the other, the findings are against those of Periakaruppan et al. (2023), who reported that the adoption of the fungicide technology is a major driver towards the reduction of potato late blight, which is a major constraint to productivity.

Conclusion

The study concluded that there is significant variability in yield between the adopters and non-adopters of agricultural technologies among Irish potato farmers. In addition, there was a significant difference in productivity per acre between the two levels of adoption. The difference between the actual yields and the counterfactual condition yields showed the average treatment effect on treat (ATT) which was associated with adoption of agricultural technologies. The ATT concluded that adopters of agricultural technologies had a possibility of decreasing their expected yield if they failed to adopt the innovations. The average treatment effect on untreated (ATU) showed that if a farmer that had not actually adopted did adopt, there was an increase in yield by almost 50%. Finally, out of the four technologies under investigation (use of chemical fertilizers, certified seeds, farm machinery and fungicides), the use of chemical fertilizer (37%) had the highest impact on yield, followed by certified seeds (35%), farm machinery (32%), and lastly, the use of fungicides (29%). The study recommends that national and county governments should develop policy regulations such as training and extension services, market access, price support, and public-private partnerships to encourage farmers to uptake use of chemical fertilizers, certified seeds, farm machinery, and fungicide. The study also recommends that both levels of government should subsidize agricultural technologies, hence reducing the cost of adoption.

Declaration

Ethical Approval Certificate

The research procedure of this study was approved by Ethics Committee of Chuka University prior to data collection (Approval date: 24th May, 2022, Ref No: CUIERC/NACOSTI 288). Moreover, the study acquired research permit from the National Commission for Science Technology and Innovation (NACOSTI) [Approval date: 15th September, 2022, Ref No: 399336].

Author Contribution

David Mwangi Kihoro: Writing the original draft, methodology and formal analysis.

Geofrey Kingori Gathungu: Supervision, conceptualization, review and editing.

Rael Nkatha Mwirigi: Supervision, conceptualization, review and editing.

Vicky Nyambura Wairimu: Data collection, conceptualization and editing.

Conflict of Interest

The authors declare no conflict of interest

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Nutrition and Antioxidant Potential of Three Cauliflower (*Brassica oleracea* L. Var. Botrytis) Cultivars Cultivated in Southern Part of Bangladesh

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ABSTRACT

This study aimed to evaluate the biochemical and nutritional profiles of three cauliflower cultivars—Valentena, Carotena, and Snow White—focusing on chlorophyll, carotenoids, anthocyanins, vitamin C, flavonoids, phenolics, and antioxidant activity. Uniform curds were harvested at 60 days post-sowing from Baratia, Dumuria, Khulna, and analyzed at Khulna Agricultural University. Valentena exhibited the highest chlorophyll content (40.06±0.39 µg/100g FW chlorophyll *a*, 28.98±3.35 µg/100g FW chlorophyll *b*), superior lycopene (8.71±0.38 µg/100g FW) levels. Carotena showed the highest total carotenoid content (60.52±1.76 µg/100g FW) and β-carotene (26.99±0.44 µg/100g FW), while Snow White had the lowest values across most parameters. Valentena also led in anthocyanins (101.56±3.9 mg/L FW) and total flavonoids (79.56±10.36 mg/100g FW), with Carotena having the highest vitamin C content (60.05±2.93 µg/g FW). DPPH assays indicated that Valentena showed the most effective antioxidant (IC_{50} = 43.65±3.56 mg/mL FW), followed by Carotena and Snow White. Hierarchical clustering and pricipal component analysis (PCA) revealed distinct biochemical profiles: Valentena and Carotena shared similarities in carotenoids and antioxidant activity, whereas Snow White differed significantly. Linear discriminant analysis identified lycopene, chlorophyll b, and β-carotene as major differentiators, highlighting the diverse nutritional and antioxidant properties of these cauliflower varieties. The findings highlight the potential of Carotena and Valentena for health-conscious consumers seeking nutrient-rich, antioxidant benefits in functional meals.

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Introduction

People from all walks of life have shown increasing interest in colorful fruits and vegetables for their disease-preventing properties (Minich, 2019). With a significant rise in chronic diseases due to various factors (Stuckler, 2008), doctors are emphasizing the consumption of foods rich in pigments and antioxidants (Saiwal et al., 2019; Arumugam et al., 2021). The science behind this recommendation is that antioxidant-rich foods contain biologically active substances that protect cells from oxidative stress and other damage (Kar et al., 2021). As the color intensity of fruits and vegetables increases, their antioxidant content and capacity also rise. Vibrant hues, particularly in dark-colored foods like red, purple, and orange/yellow, indicate higher levels of beneficial pigments and antioxidants (Cömert et al., 2020; Sharma et al., 2021). Therefore, researchers are working to develop colored variants of traditional varieties with the aim of increasing their nutritional value, especially their bioactive components.

The Brassicaceae family is renowned for its health-promoting phytochemicals, which empower its species to reduce chronic non-communicable diseases (Ahmed & Ali, 2013; Radünz et al., 2024). Brassica vegetables, in particular, boast a high nutritional composition, including vitamins (carotenoids, tocopherol, ascorbic acid, folic acid), carbohydrates, amino acids, minerals (Cu, Zn, P,

Mg, etc.), and various phytochemicals such as indole phytoalexins, glucosinolates, and phenolics (Jahangir et al., 2009; Biondi et al., 2021; Soengas et al., 2021). These phytochemical properties enable Brassica vegetables to reduce age-related chronic illnesses, such as cardiovascular health issues (hypertension, stroke), degenerative diseases, obesity, type-2 diabetes, osteoporosis, and various cancers (Favela-González et al., 2020). Cauliflower, a member of the Brassicaceae family, is highly regarded for its nutritional value and health-promoting properties. This versatile vegetable is a staple in many diets worldwide, prized not only for its culinary applications but also for its rich content of essential nutrients and bioactive compounds (Picchi et al., 2020). Like other Brassica vegetables, its leaves and curd are excellent sources of antioxidants like phenolic compounds, carotenoids, glucosinolates and vitamins (Picchi et al., 2020); as well as dietary fibers, and other phytochemicals (Bux Baloch et al., 2015). Cauliflower is also a rich source of glucosinolate, a well-known anticarcinogenic compound. These bioactive compounds contribute to reducing the risk of chronic diseases, including various cancers and coronary heart disease (Picchi et al., 2020).

Anthocyanins and carotenoids are pigments that are important to plant biology and human health (Jayakumar et al., 2023). In plants, these pigments are necessary for photosynthesis and UV protection (Markwell & Namuth, 2003; Roleda et al., 2004). Carotenoids, which are present in orange and yellow cauliflower varieties, are rich sources of antioxidants and are precursors to vitamin A, which is important for immunological response, skin health, and vision (Selly Msungu et al., 2022; Çoka & Akınoğlu, 2023). In addition to giving purple pigmentation, anthocyanins have potent antioxidant properties that shield cells from oxidative damage and lower inflammation (Frestasya & Pangsibidang, 2024). According to studies conducted by SellyMsungu et al. (2022) and Jayakumar et al. (2023), dietary consumption of plants' pigments is linked to a decreased risk of chronic illnesses like cardiovascular disease and some types of cancer. Once more, plants' color, flavor, and ability for withstanding both biotic and abiotic stresses are all influenced by phenolic compounds, a diverse group of secondary metabolites (Kelebek & Selli, 2012; Khanday et al., 2024; Salehi & Safaie, 2024). According to Phuyal et al. (2020), phenols are known for their antioxidant properties, which reduce oxidative stress and neutralize dangerous free radicals to improve human health. Increased phenol intake has been linked to a lower incidence of long-term conditions such cancer, diabetes, and cardiovascular disease (Rodriguez-Mateos et al., 2024). Furthermore, phenols possess anti-inflammatory, anti-mutagenic, and anti-carcinogenic properties, making them essential for preserving health and averting illness (Phuyal et al., 2020; Alsaadi, 2024). Fruits, vegetables, and drinks like tea and wine are rich sources of flavonoids, a subclass of phenolic chemicals. These substances are well-known for their vivid hues and for helping to tint plants (Davies et al., 2022). In terms of health benefits, flavonoids are powerful antioxidants and play a significant role in reducing the risk of chronic diseases(Alsaadi, 2024). They help improve cardiovascular health by enhancing endothelial function, reducing blood pressure, and decreasing LDL cholesterol levels (Hashizume & Tandia, 2024). Additionally, flavonoids possess anti-inflammatory and anti-cancer properties, support immune function, and may improve cognitive function and reduce the risk of neurodegenerative diseases (Spagnuolo et al., 2018).

Cauliflower is an important crop in areas where agriculture is the primary source of income, such as southern Bangladesh. Numerous cauliflower varieties are grown in the area due to its good climate and soil, each of which has a distinct nutritional profile and antioxidant capacity. Colorful cauliflower cultivars have recently been produced by researchers to improve nutrient and antioxidant consumption. Nevertheless, nothing is known about these new cultivars' pigment richness, nutritional makeup, and antioxidant potential (total phenolics and flavonoids) in this area. In this study, three cauliflower cultivars—two colorful variants (orange/yellow and purple) and the conventional white cultivar—grown in southern Bangladesh are evaluated for their nutritional makeup and antioxidant potential. We anticipate that our study can bring light on the distinctive nutritional profiles and antioxidant qualities of these colorful new cultivars and offer insightful information about their scientific advantages.

Materials and Methods

Sample Collection

On November 23, three cauliflower cultivars (Snow White, Carotena, and Valentena) curd of uniform age (60 days after sowing/20 days after flowering) and size were collected from a cauliflower cultivation field in Baratia, Dumuria, Khulna and placed in ziplock bags. The collected sample was then taken to the Crop Botany Department Laboratory at Khulna Agricultural University in Khulna for further chemical analysis. From each cultivar, four individual plants were selected, and one curd was harvested from each plant, ensuring that each curd represented one of the four replications (Figure 1).

Figure 1. Three cauliflower (*Brassica oleracea* L. Var. Botrytis) cultivars collected from Baratia, Dumuria, Khulna for pigment, antioxidant and nutrition analysis.

Determination of Pigment

The concentrations of photosynthetic pigments were measured using a modified spectrophotometric technique based on Lichtenthaler (1987) method. Exactly 0.5 grams of cauliflowers' leaf and curd (composite sample) were finely chopped and placed in a small vial containing 10 mL of 80% ethanol. The vials were kept in the dark for 10 days to allow pigment extraction. A spectrophotometer (Shimadzu UV-1280, Kyoto, Japan) was used to measure absorbance at wavelengths of 480, 453, 495, 505, 645, and 663 nm. Subsequently, the concentrations of chlorophyll *a*, chlorophyll *b*, carotenoids, lycopene, β-carotene, and lutein were determined using specific equations (Sumi et al., 2024).

Chlorophyll *a* = (λ663 × 0.999 - λ645 × 0.0989) × V/W

Chlorophyll *b* = (λ645 × 1.77 - λ 663 × 0.328) × V/W

Total Chlorophyll = Chlorophyll *a* + Chlorophyll *b*

Total Carotenoids = {(λ663 × 0.114 - λ645 × 0.638) + λ480} × V/W

Lycopene = (λ663 × 0.0458 + λ645 × 0.204 + λ505 × 0.372 − λ453 × 0.0806) × V/W

β-carotene = (λ663 × 0.216 − λ645 × 1.22 − λ505 × 0.304 + λ453 × 0.452) × V/W

Lutein = (λ480 × 11.51 –λ495 × 20.61) × V/W

In this context, λ663 represents the absorbance at a wavelength of 663 nm, λ645 denotes the absorbance at 645 nm, λ505 signifies the absorbance at 505 nm, λ495 indicates the absorbance at 495 nm, λ480 corresponds to the absorbance at 480 nm, and λ453 pertains to the absorbance at 453 nm.

Vitamin C Determination

The 2,6-dichlorophenol indophenol dye solution, which changes color from blue to red when ascorbic acid is present, is the basis for the titrimetric determination of vitamin C. With ascorbic acid, this reaction is both quantitative and selective within the concentration range of 10–35µg/mL. The indophenol dye solution and meta-phosphoric acid were among the reagents utilized. A known weight curd tissue sample was extracted using 3% meta-phosphoric acid, and the sample was then diluted to a predetermined volume. When an aliquot of this solution was titrated with the indophenol dye solution and a persistent pink color developed, the reaction had reached its endpoint. After the dye solution was adjusted using a standard ascorbic acid solution, the dye factor was determined. In the end, the vitamin C content was calculated using the formula below. This process was modified in light of Xiao et al. (2012).

$$\text{Vitamin C (µg/g FW)} = \frac{e \times d \times b}{c \times a \times 100}$$

Where, a represents the weight of the sample, b denotes the volume made with metaphosphoric acid, c indicates the volume of the aliquot taken for estimation, d stands for the dye factor, and e signifies the average burette reading for the sample.

Determination of Anthocyanin

Using a mortar and pestle, the 3 g fresh curd sample were homogenized in 30 mL of 99.9% ice-cooled methanol. After that, the mixture was sealed in a glass bottle and left for half an hour in the dark. Two distinct 1.5 mL Eppendorf tubes were filled with the supernatant extracts. Following a 5-minute centrifugation at 15,000 rpm, the tubes were refrigerated at -10°C to measure the anthocyanin, phenol, flavonoid, and DPPH radical scavenging capacity. Using a modified technique that combined the pH differential method with spectrophotometry, the total amount of monomeric anthocyanins was ascertained (Gordillo et al., 2018). The foundation of this technique is the way the anthocyanin's structure changes in response to pH in two buffer solutions (pH 1.0 and pH 4.5). The monomeric anthocyanins concentration is directly proportional to the difference in absorbance between the pH 1.0 and pH 4.5 solutions, as per this approach. At 510 nm and 700 nm, the absorbance of the samples buffered in two distinct pHs is measured. The most prevalent anthocyanin, cyanidin-3-glucoside, is measured using the following equation to determine the total amount of monomeric anthocyanins (TAMA), which is expressed as mg/L (Khoo et al., 2017; Galvão et al., 2020).

$$\text{TAMA (mg/L)} = \frac{(A510-A700)-(B510-B700).MW*DF*100}{\varepsilon \cdot l}$$

Here, at 510 nm, A510 and B510 represent the absorbance for pH 1 and pH 4.5 buffers, respectively. At 700 nm, A700 and B700 represent the absorbance for pH 1 and pH 4.5 buffers, respectively. The variables that represent the molar mass (MW) of cyanidin-3-glucoside (449.2 g/mol), dilution factor (DF), molar extinction coefficient (ε) (26,900 L/mol/cm), conversion factor (1000) from g to mg, and wave path (in centimeters) in the cuvette are all represented.

Determination of Total Phenolic Content

To quantify the total phenolic compound content, a technique adapted from (Albano & Miguel, 2011) was used. For this determination, gallic acid served as the standard. Various concentrations of gallic acid or plant extracts were added to test tubes, followed by 16µL Folin–Ciocalteu reagent and 3mL of 10% sodium carbonate solution. The mixture was left in the dark at room temperature for 30 minutes. The absorbance of each sample was then measured at 760nm wavelength to indicate the overall phenolic content. These absorbance values were plotted against their corresponding concentrations, generating a linear relationship that formed a standard curve used to determine the total phenolic content in the test samples (Sumi et al., 2024).

Determination of Total Flavonoid Content

The flavonoid contents of the leaf and stem extracts were calculated using catechin as a reference. More specifically, 300 µL of each $AlCl_3$ and $NaNO_2$ solution was reacted with 1 mL of previously obtained plant extracts. After the mixture was allowed to sit at room temperature for five minutes, two milliliters of NaOH solution and ten milliliters of distilled water were added. The mixture was then vortexed and allowed to sit for 30 minutes. As per Baba & Malik, (2015), the compound's total flavonoid concentration (TFC) was determined by measuring the absorbance at 510 nm. The TFC was expressed as follows: one gram of fresh extract was equal to a microgram of catechin.

DPPH Radical Scavenging Capacity Assay

Using 2-diphenyl-1-picrylhydrazyl radical (DPPH), the ability of medicinal plant extracts to scavenge free radicals was evaluated using the procedure outlined by (Brand-Williams et al., 1995). Stable free radical DPPH, which has a distinct violet hue, turns yellow as the sample's antioxidants scavenge the free radicals. The transition from

violet to yellow in color corresponds to the level of radical scavenging action. One milligram of DPPH in methanol was mixed with different quantities of plant extracts that were made using methanol and previously extracted material. The materials were completely mixed by vortexing, and then they were incubated for 30 minutes at room temperature (24–30°C). A DR 6000 UV spectrophotometer was used to measure the reduction in absorbance at 517 nm. Using the following formula, the proportion of scavenging activity was determined:

$$\text{Scavenging Activity (\%)} = \frac{(Ac-As)\times 100}{Ac}$$

Where, A*s* is the sample absorbance and Ac is the control absorbance (without extract). The IC_{50} value, representing the concentration of antioxidant required to scavenge 50% of the free radicals, was determined by plotting the percentage of radical scavenging activity against the extract concentration.

Statistical Analysis

Minitab 17.3 was used to do the statistical analysis. After determining whether differences were significant using one-way ANOVA, Tukey's HSD test ($p \leq 0.05$) was run. Using euclidean distances, a hierarchical clustering analysis was performed and a heatmap was made using the "pheatmap" package in R 4.3.2. Principal component analysis (PCA) was carried out using the "GGally" and "factoextra" programs. The correlation study was performed using the "Corrplot" software (Yasmin et al., 2024). The "MASS" program was utilized for Linear Discriminant Analysis (LDA).

Result and Discussion

Chlorophyll Content of Three Cauliflower Cultivars

The chlorophyll content varied significantly among the Valentena, Carotena, and Snow White cauliflower varieties. Valentena exhibited the highest chlorophyll levels, demonstrating superior photosynthetic potential with a chlorophyll *a* (Chl a) content of 40.06±0.39 µg/100g FW (100%) and a chlorophyll *b* (Chl b) content of 28.98±3.35 µg/100g FW (100%), leading to a total chlorophyll (TChl) value of 69.04±3.64 µg/100g FW (100%) (Table 1). Carotena and Snow White had considerably lower chlorophyll levels, although their chlorophyll content was not significantly different. Carotena showed moderate values with Chl a at 77.46%, Chl b at 36.78%, and a TChl of 60.38%, while Snow White recorded the lowest with Chl a at 71.85%, Chl b at 24.35%, and a TChl of 51.91% (Table 1).

Anthocyanin of Three Cauliflower Cultivars

Figure 2A summarized the anthocyanin content in the curds of three cauliflower cultivars: Valentena, Carotena, and Snow White.

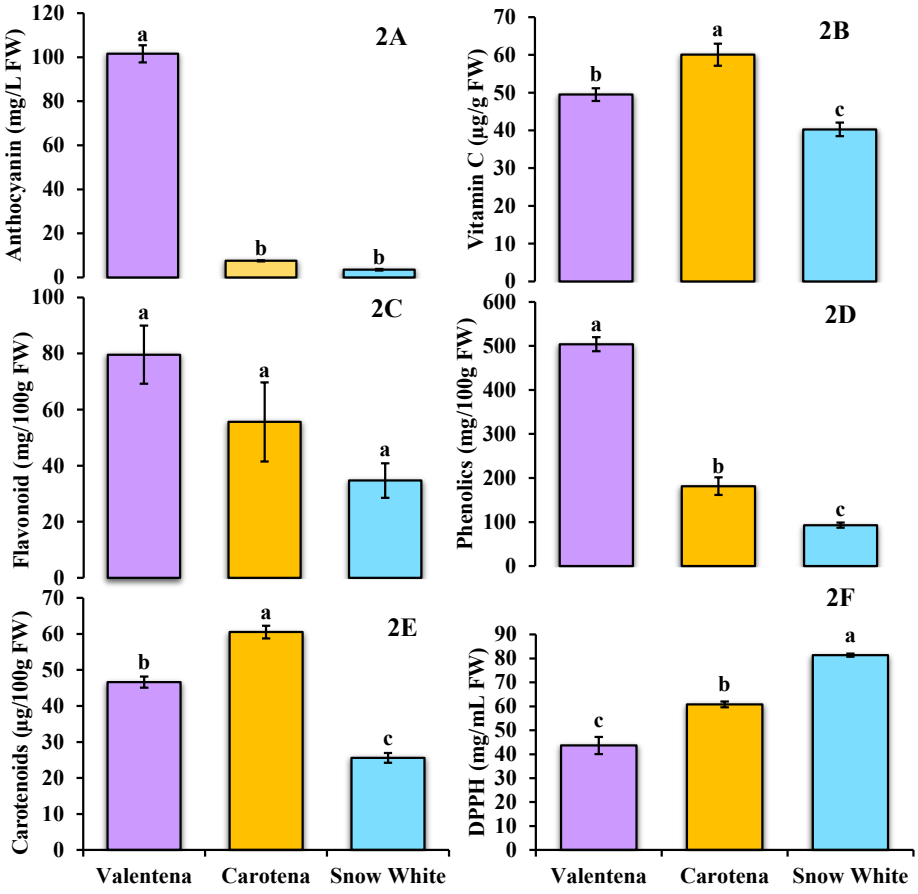

Figure 2: Content of anthocyanin

(A), vitamin C (B), total soluble flavonoids (C), total phenolics (D), total carotenoids (E), and IC50 value for DPPH scavenging (F) across three cauliflower cultivars. Error bars represent the standard error of the mean (SEM, n = 4). Mean values with different letters indicate significant differences at the 5% level.

Table 1. Comparison of chlorophyll and carotenoid content across three cauliflower cultivars (fresh weight basis)

Cultivars	Chlorophyll (µg/ 100g FW)			Carotenoids (µg/ 100g FW)		
	Chl a	Chl b	TChl	Lycopene	β-Carotene	Lutein
Valentena	40.06±0.39[a]	28.98±3.35[a]	69.04±3.64[a]	8.71±0.38[a]	7.75±1.71[b]	20.04±4.07[a]
Carotena	31.03±2.08[b]	10.66±1.04[b]	41.69±1.36[b]	5.93±0.47[b]	26.99±0.44[a]	26.20±25.60[a]
Snow White	28.78±2.14[b]	7.06±1.61[b]	35.84±2.29[b]	4.76±0.29[b]	1.37±0.79[a]	10.86±0.76[a]

* Chl a = chlorophyll *a*; Chl b = chlorophyll *b*; TChl = total chlorophyll. No significant difference ($p<0.05$) between values within each column that share the same letter(s).

Valentena had a markedly higher average anthocyanin content at 101.56±3.90 mg/L FW (100%), distinguishing it from the other cultivars. In contrast, Carotena and Snow White had significantly lower anthocyanin contents, 7.43% and 3.43%, respectively (Figure 2A). The letters (a, b, c) following the SEM values indicated that Valentena's anthocyanin level was significantly different from both Carotena and Snow White, which did not differ significantly from each other.

Carotenoids of Three Cauliflower Cultivars

Carotena had the greatest average total carotenoid content (60.52±1.76 µg/100g FW), much higher than Snow White's and Valentena's combined values of 46.62 ± 1.56 µg/100g FW and 25.58±1.36 µg/gFW (Figure 2E). Once more, Valentena had the greatest lycopene concentration of any cauliflower cultivar, averaging 8.71±0.38 mg/100g; for reference, this was expressed as 100%. Snow White had 54.65% of lycopene concentration, whereas Carotena had 68.09% (Table 1). Carotena had the greatest average concentration of β-carotene (26.99±0.44 µg/100g FW; 100% for comparison). Snow White had 5.07% β-carotene concentration, compared to 28.72% in Valentena. Carotena had the highest level of lutein, averaging 26.20±25.60 µg/100g FW, or 100%. In contrast, Snow White had 42.27% and Valentena had 77.04% (Table 1).

Vitamin C of Three Cauliflower Cultivars

With an average of 60.05±2.93 µg/g FW, Carotena curd had the highest vitamin C content among the cultivars, making it very rich in this nutrient, which is renowned for its roles in immune function and antioxidant activity. Valentena was the second highest with an average vitamin C content of 49.49±1.69 µg/g FW. Snow White had the lowest vitamin C content, averaging 40.25±1.81 µg/g FW (Figure 2B). For those looking to increase their vitamin C intake, Carotena may be the most advantageous option, while Snow White and Valentena had moderate to low concentrations of this nutrient.

Total Flavonoid content of Three Cauliflower Cultivars

Figure 2C presented the total flavonoid content in the curd of three cauliflower cultivars: Valentena, Carotena, and Snow White. Valentena had the highest average total flavonoid content at 79.56±10.36 mg/100g FW. Carotena had an average flavonoid content of 55.60±14.12 mg/100g FW, and Snow White had an average of 34.70±6.16 mg/100g FW (Figure 2C). Despite the differences in average flavonoid content, the notation 'a' after the SEM values indicated that there was no statistically significant difference among the cultivars. This means the total flavonoid content was consistent across Valentena, Carotena, and Snow White.

Total Phenolic Content of Three Cauliflower Cultivars

Valentena curd showed the highest phenolic content with an average of 503.83±15.87 mg/100g FW, indicating a robust concentration of phenolic compounds known for their antioxidant properties. Carotena followed with an average phenolic content of 181.55±19.78 mg/100g FW, which was significantly lower than Valentena. Snow White had the lowest phenolic content, averaging 92.95±5.82 mg/100g FW. The different letters (a, b, c) following the SEM values indicated statistically significant differences among the cultivars.

DPPH radial Scavenging Potential of Three Cauliflower Cultivars

Lower values of DPPH indicate better antioxidant capacity. Among the three cauliflower cultivars, Valentina demonstrated the highest antioxidant potential with an IC_{50} value of 43.65±3.56 mg/mL FW (100%). Carotena follows with a value of 139.26%, indicating slightly less effective antioxidant properties than Snow White. Snow White has the lowest antioxidant potential among the three, with a DPPH value of 186.46%. Valentena as the most potent antioxidant, followed by Carotena, with Snow White being the least effective in scavenging DPPH radicals (Figure 2F).

Hierarchical Clustering and Co-Clustering of Variety and Traits

The heatmap with dendrogram in Figure 3 highlighted the similarities and differences among cauliflower cultivars (Valentena, Carotena, Snow White) based on pigments, phytochemicals, nutritional, and antioxidant parameters. Valentena and Carotena showed higher values for certain parameters like TPC and CARO, indicating similarities in antioxidant and carotenoid profiles. Snow White stood out with generally lower values across most parameters, suggesting a distinct biochemical profile. The dendrograms revealed hierarchical clustering of both cultivars and parameters, showing relationships such as the close association between DPPH and TFC, and the grouping of traits like ANT, LCP, CHB, TCHL, TPC, and CHA. Clusters indicated that antioxidant activity and flavonoid content were the highest in Valentena, the lowest in Snow White, and average in Carotena.

Correlation Analysis

The correlation matrix provided showed the pairwise correlations between different parameters: ANT, TFC, TPC, DPPH, VTC, CHA, CHB, TCHL, LCP, BCAR, LUT, and CARO. Each cell in the matrix indicated the correlation coefficient between two parameters, ranging from -1 (perfect negative correlation) to 1 (perfect positive correlation), with 0 indicating no correlation.

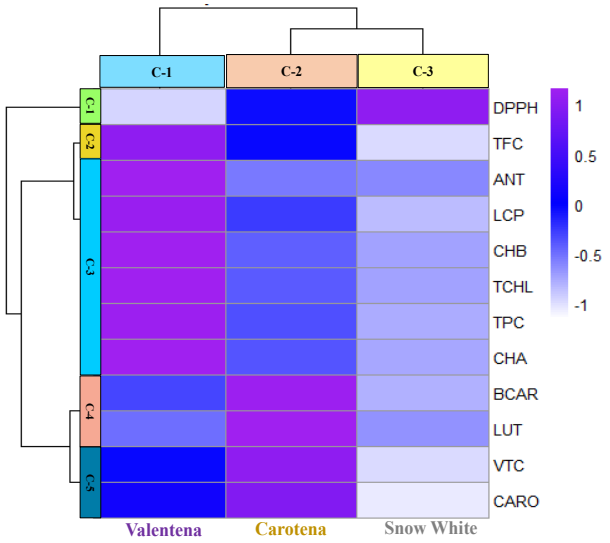

Figure 3. Hierarchical co-clustering of three cauliflower traits and cultivars based on standardized pigment, antioxidant, and nutrient values. Colors reflect relative values (-1 to +1), with purple indicating high and white low.

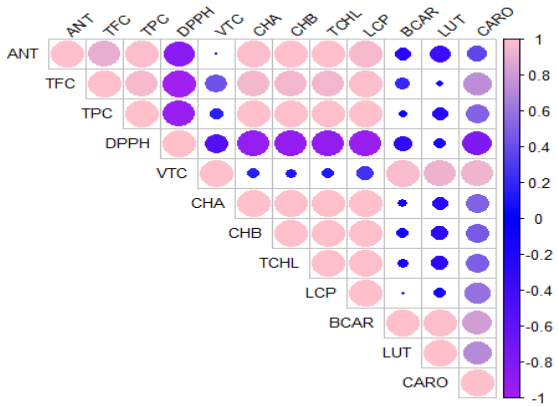

Figure 4: Correlation matrix for three cauliflower cultivars, with pink circles indicating positive correlations, purple circles indicating negative correlations, and circle size reflecting strength (-1 to +1).

Table 2. Eigenvalues and latent vectors of three cauliflower cultivars across the initial three principal components

Variable	Principal Components		
	PC1	PC2	PC3
Extracted eigenvalues	8.02	3.98	3.44e-31
Proportion of varience	0.66	0.33	0.00
Explained variance (%)	6.69e-01	3.31e-01	2.87e-32
Cumulative varience (%)	66.87	100	100
Standard deviation	2.83	1.99	3.80e-16
Traits	Eigen vectors		
ANT	1.008	-0.732	0.455
TFC	-0.112	0.095	-0.064
TPC	-4.629	-0.680	0.056
DPPH	-0.912	1.452	0.278
VTC	-0.148	0.375	-0.183
CHA	0.484	0.175	0.136
CHB	1.206	-0.293	0.180
TCHL	0.091	0.197	0.147
LCP	1.396	-0.246	0.158
BCAR	1.192	-0.361	-0.244
LUT	0.288	0.003	-0.540

This matrix was useful for understanding how these parameters related to each other. For instance, ANT, TPC, CHA, CHB, and TCHL showed strong positive correlations among themselves, while DPPH exhibited strong negative correlations with several parameters. Variable VTC showed moderate positive correlations with BCAR, LUT, and CARO, indicating some degree of positive association. This matrix aided in determining which variables tended to vary together or in opposite directions, revealing potential relationships and dependencies within the dataset.

Principal Component Analysis

The results of the Principal Component Analysis (PCA) revealed essential insights into the structure and variance of the dataset. PCA identified three principal components (PC1, PC2, and PC3) with corresponding eigenvalues of 8.02, 3.98, and close to zero, respectively, indicating that PC1 explained a substantial 66.9% of the total variance, while PC2 contributed 33.1% (Figure 5). PC3, with a nearly negligible eigenvalue, suggested minimal contribution to the dataset's variance (Table 2). The eigenvectors or traits highlighted the weights and directions of each original variable (ANT, TFC, TPC, etc.) within these components, illustrating their relative importance in shaping the dataset's variability. This analysis underscored the effectiveness of PCA in reducing dimensionality while preserving key information, allowing for clearer interpretation of underlying patterns and relationships among the variables studied.

Coefficients Of Linear Discriminants

Table 3 presents the results of the Linear Discriminant Analysis (LDA) for cauliflower traits, showing the coefficients for two linear discriminants (LD1 and LD2) and their proportions of trace. LD1 explained 63.04% of the variance, while LD2 accounted for 36.96%.

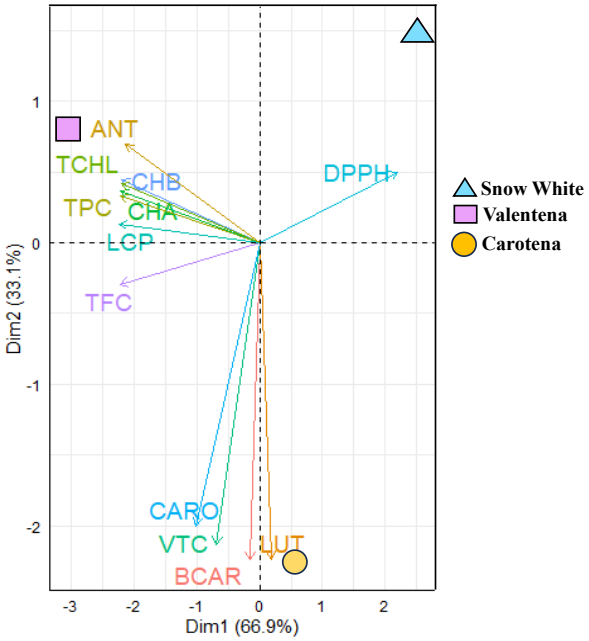

Figure 5. Principal Component Analysis (PCA) visualizes pigment, antioxidant, and nutrient values of three cauliflower cultivars, with arrows from centroids indicating dissimilarities. Vector length reflects variable contribution strength, while angles depict interactions; small angles indicate high positive correlations

Table 3. Linear Discriminant Analysis and Coefficients for Cauliflower Traits in LD1 and LD2

Variable	Linear Discriminants	
	LD1	LD2
Proportion of trace (%)	63.04	36.96
Studied traits	Coefficients	
ANT	0.204	-0.042
CARO	0.088	0.144
CHA	0.083	0.016
LCP	2.730	-0.057
BCAR	0.709	0.680
LUT	0.311	0.482
TCHL	0.032	0.012
CHB	1.971	-0.454
VTC	0.210	0.098
TFC	0.105	0.174
TPC	0.060	-0.012
DPPH	-0.198	-0.026

The coefficients indicate the contribution of each trait to the discriminants: for example, LCP and BCAR had high coefficients in LD1, suggesting they significantly influence this component, whereas traits like DPPH and TPC had lower coefficients. LD1 and LD2 together highlight which traits are most influential in distinguishing between groups, aiding in the classification and interpretation of cauliflower characteristics.

The research highlights the significant variations in chlorophyll, carotenoid, anthocyanin, and vitamin C content among different cauliflower cultivars, emphasizing their implications for crop quality, nutritional value, and health benefits. Valentena cauliflower exhibited the highest chlorophyll content, particularly Chl a and Chl b in their leaves. Izadpanah et al. (2024) found that purple and orange cauliflower cultivars also had higher chlorophyll levels in their leaves, consistent with our findings. However, their results were higher, likely due to differences in cultivars, cultivation methods, environmental conditions, and analytical techniques. According to Izadpanah et al. (2024) and Sherin et al. (2022), chlorophyll-rich cultivars have better photosynthetic efficiency and growth potential. Also, previous research suggesting chlorophyll-rich cultivars offer increased nutritional benefits due to their robust photosynthetic and antioxidant activities (Lanfer-Marquez et al., 2005; Sherin et al., 2022; Martins et al., 2023). In our study, Carotenoids, such as β-carotene and lutein, were most abundant in Carotena, underscoring its nutritional value and antioxidant properties. According to Izadpanah et al. (2024), orange cauliflower cultivars' dried leaves had significant concentrations of lutein, β-carotene, and carotenoids than other studied cultivars. These findings validate our study. Again, they had significantly greater values than we had, probably because we were focused on fresh curds than dried leaves, and because our farming methods and the environment were different. Crupi et al. (2023) and Johra et al. (2020) emphasize the health benefits of β-carotene-rich diets in improving antioxidant defense and eye health. Moreover, the importance of carotenoids in reducing oxidative stress and mitigating chronic diseases has been emphasized in several studies (Koca Bozalan & Karadeniz, 2011; Martí et al., 2016; Muscolo et al., 2024). Anthocyanins, known for their vibrant colors and antioxidant properties, have been extensively studied in various fruits and vegetables, including cauliflower (Scalzo et al., 2008; Mattioli et al., 2020). The potential health advantages of anthocyanin-rich diets, such as reduced inflammation and cardiovascular protection, are well-documented (Mozos et al., 2021; Mohammadi et al., 2024). In our study, Valentena showed significantly higher anthocyanin content compared to Carotena and Snow White, similar to findings in purple cauliflower and red cabbage that correlate higher anthocyanin levels with enhanced antioxidant capacity (Scalzo et al., 2008). Again, Singh et al. (2020) reported a significant variation in anthocyanin content within the F2 population of cauliflower curds, ranging from 3.81 to 48.21 mg per 100 g of fresh weight. They also observed that dark purple curds exhibited higher anthocyanin levels compared to light purple or white curds. These findings closely align with the results of our study. Carotena's high vitamin C content highlights its nutritional superiority, in line with studies by several studies emphasizing vitamin C's role in reducing oxidative stress and improving immune response (Kükürt & Gelen, 2024; Tewari et al.; 2017; Uddin et al., 2021). This finding also aligns with research comparing vitamin C levels in nutrient-dense foods like bell peppers and strawberries (Kishwar et al., 2019; Afnani et al., 2023). Moreover, the ascorbic acid range was consistent with the earlier Vanlalneihi et al. (2020) findings.

Valentena's high total flavonoid and phenolic content further underscores its significant antioxidant properties. This aligns with Dos Reis et al. (2015) and recent studies demonstrating the health benefits of flavonoid- and phenolic-rich foods in reducing oxidative stress, inflammation, and chronic disease risk (Sumi et al., 2024; Yang et al., 2021; Liu et al., 2023). Valentena's strong antioxidant capacity, indicated by its low IC_{50} value in the

DPPH assay, supports previous research on the robust relationship between high flavonoid and phenolic levels and antioxidant capacity (Lyu et al., 2023; Sumi et al., 2024). Bhandari et al. (2015) concluded that the Asia purple cultivar has the highest antioxidant activity in its florets due to its considerably higher levels of total phenols, and total flavonoids. The findings validate our results.

Multivariate statistical analyses, such as hierarchical clustering and PCA, were crucial in identifying cultivar-specific traits and biochemical mechanisms influencing nutritional quality (Aleem et al., 2021;Tawonga, 2024). This approach, similar to studies by Granato et al. (2018) and Sharma et al. (2017), enhances understanding of biochemical diversity and assists in identifying cultivars with superior health benefits. One of the crucial methods for dimensionality reduction, machine learning, and pattern recognition is linear discriminant analysis (LDA) (Li et al., 2021). LDA results highlighted key biochemical traits like lycopene, chlorophyll b, β-carotene, anthocyanin, and lutein as significant discriminators, consistent with research on other crops (Bhandari et al., 2016; Fioroni et al., 2023). Since of their antioxidant qualities, these substances are essential to human health since they lower the chance of developing chronic illnesses. Overall, the study reinforces the importance of understanding plant biochemistry to enhance crop quality, nutritional value, and health benefits.

Conclusion

The study focused on diverse cauliflower cultivars, revealing significant biochemical differences that impact their nutritional profiles and health benefits. Valentena cauliflower was found to have the highest level of anthocyanins and chlorophyll, which enhanced its antioxidant capacity and possible health advantages. Superior quantities of lutein and β-carotene were demonstrated by carotena, underscoring its nutritional significance. Carotena's strong vitamin C concentration further emphasizes its significance for antioxidant defense and immunological support. Valentena is a cultivar that is advantageous for consumers who are health-conscious due to its strong antioxidant qualities and high flavonoid and phenolic content. PCA and other multivariate analyses revealed key biochemical traits that differentiate cultivars, guiding future breeding and nutritional enhancement efforts. Future research should explore optimizing cultivation practices for enhancing the beneficial compounds identified in cauliflower cultivars.

Declarations

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Competing Interests

The authors declare that there is no conflict of interest in the article.

Author Contributions

- M.J.S. conceived and designed the experiments, performed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the article, and approved the final draft.
- S.A.S. performed the experiments, authored of the article, and approved the final draft.
- T.K.R. authored or reviewed drafts of the article and approved the final draft.
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- M.J.D. authored or reviewed drafts of the article, analyzed the data, and approved the final draft.
- M.A. authored or reviewed drafts of the article, and approved the final draft.
- N.U. supervision and curated data, prepared figures and/or tables, funding acquisition, authored or reviewed drafts of the article, and approved the final draft.

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Growing Degree Day Climatology in Aydın, Türkiye

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ABSTRACT

Plants need to accumalate heat to complete a particular or whole growth period. This accumalation depends on temperature thresholds above or below which plant growth ceases, and on air temperature. It can be speculated that more heat accumulation is available for plants due to rapid warming within three or four decades. This study presents more recent heat accumulation for plants, quantified using a useful index called growing degree day (GDD), for five locations (Söke, Kuşadası, Aydın, Sultanhisar and Nazilli) in Aydın, Türkiye, during the latest climatic normal period from 1991 to 2020. GDD values were calculated both in monthly basis from March through October, and in daily basis from March 1st to October 31st. Monthly GDD averages, as expected, showed a pattern that increased from March to July or August, then decreased thereafter till October. Range and standart deviation showed approximately an opposite pattern, suggesting higher uncertainity in relatively colder months. The results are expected to provide farmers or agricultural practitioners with the latest averages of GDD to predict plant growth and development.

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Introduction

Growing degree days (GDD) concept, also known as "thermal time", "heat units" or "growth units" (Anandhi, 2016), is a frequetly used proxy to assess crop development (Gordon & Bootsma, 1993). It is first postulated as early as 1735 by René-Antoine Ferchault de Réaumur, stating that "organisms need to accumulate a number of heat units unique to that organism in order to initiate growth and to develop or mature" (Mix et al., 2010). GDD is simply the sum of temperature, during growing season or a spesified period, above a spesific temperature threshold (i.e., base temperature, T_{base}), below which crop development ceases. There is also an upper temperature threshold (T_{upper}), above which crop is dormant. T_{base} and T_{upper} are spesific for each species. GDD is used to estimate or predict plant growth and development, occurrences of insects, plant maturity and harvest timing (Radzka, 2021; Kadıoğlu & Şaylan, 2001).

Global surface temperature increased from 1850–1900 to 2011–2020 by 1.09°C (Arias et al., 2021). Since the 1980s, each decade has been warmer than the previous one (Ansari & Landin, 2022), and the decade 2011-2020 was the warmest one on record (United Nations Climate Change, 2022). Particularly western Türkiye, along with other Mediterranean countries, is considered to be affected substantially from present and future warming (Caloiero & Guagliardi, 2021; Goubanova & Li, 2007). Previous studies have documented that substantial temperature increases have been observed in western Türkiye, including Aydın and environs (Hadi & Tombul, 2018; Çelebioğlu et al., 2021; Yeşilırmak & Atatanır, 2021). These results suggest that, if adverse impacts of extreme high temperatures are not accounted for, during the most recent decades more heat is available for crop development. Revealing the accumulated GDD during a specified period within a year provides insight into the latest status of heat accumulation. It is aimed in this study to document average GDD accumulation calculated for the latest climatic normal period from 1991 to 2020 in the province Aydın, western Türkiye. The results are expected to provide agricultural practitioners or farmers the latest averages of GDD to predict plant growth and development.

Materials and Methods

Daily maximum and minimum temperature (T_{max} and T_{min}, respectively) data recorded at five weather stations in Aydın, Türkiye, were used. Data were supplied from the State Meteorological Agency of Türkiye. The weather stations are shown on a map in Figure 1 and listed in Table 1. The stations are located within the administrative borders of the povince Aydın. Typical mediterranean climate prevails over the study area, characterized by hot and dry summers, and mild and rainy winters.

Table 1. Weather stations and their geographical coordinates (The State Meteorological Service of Türkiye, 2022)

No	Station No	Station name	Latitude (N)	Longitude (E)
1	17234	Aydın	37.8402	27.8379
2	17232	Kuşadası	37.8597	27.2652
3	17860	Nazilli	37.9135	28.3437
4	17850	Sultanhisar	37.8843	28.1504
5	17881	Söke	37.7049	27.3827

Figure 1. The locations of weather stations

T_{max} and T_{min} data used in the study cover the period from 1991 to 2020. The period 1991 – 2020 is the latest climatic normal period, based on the definition of World Metetorological Organization (Bonacci, 2022). The weather stations are operated by State Meteorological Agency of Türkiye.

T_{max} and T_{min} records were subjected to a basic quality control procedure: T_{min}>T_{max} and non-existent days (Klein Tank et al., 2002). Detected miscodings were set to a missing value. Overall, missing data were no more than 0.15% at any station. Missing data were filled by using data of neighboring stations with simple linear regression (Hu et al., 2012). Annual mean series of T_{max} and T_{min} were examined for homogeneity using the double mass curve method and no apparent breakpoint was detected (Hu et al., 2012).

For a specified period, accumulated GDD is calculated using the equation 1 (Anandhi, 2016):

$$GDD = \sum \left[\frac{(T_{max} - T_{min})}{2} - T_{base} \right] \quad (1)$$

where $T_{base\ is}$ the base temperature (or, lower threshold temperature) below which crop growth does not occur. Furthermore, an upper temperature threshold (T_{upper}) above which crop growth ceases is also considered. In cases of T_{max} or T_{min} being above T_{upper} or below T_{base}, T_{max} or T_{min} is set to T_{base} or T_{upper} if they are below T_{base} or above T_{upper}, respectively (Paparrizos & Matzarakis, 2017). Five T_{base} (0, 5, 7, 10 and 15°C) and two T_{upper} (30 and 35°C) were selected. Accumulated GDDs were calculated on montly basis from March through October, and in daily basis from March 1st to October 31st.

Results and Discussion

Mean monthly GDD from March to October are shown in Figure 2 as bars, with the respective GDD values being presented at tips of bars, which makes the results more easily readable. The most prominent pattern is that mean GDDs have an increasing tendency from March till mid-summer, with peak values in July or August, then decreasing toward October. This pattern is, with no exception, the same for all T_{base} and T_{upper} combinations, and consistent with temperature evolution throughout year, also with expectation that heat accumulation of a colder period is fewer than that of a warmer period. March is the month with the lowest heat accumulation, varying roughly from 44 to 406°C, depending on thresholds and station. March is followed by april and october. The highest heat accumulations (i.e., GDD values) take place in july or august, which ranges roughly from 300 to 900°C depending on station and threshold. One can find or calculate, in terms of averages over the latest normal climatic period from 1991 to 2020, accumulated heat for a desired crop when a particular growth stage is attained.

As shown in Figure 2 for a given T_{base} and station, GDD values for both T_{upper} are the same or very close to each other in relatively colder months, namely in march, april and october at Kuşadası and Söke, and in march and april at other stations. On ther other hand, as time progresses and weather becomes hot, the two diverges and the difference between them becomes more evident in warmer months particularly in july or august. Up to 20% more heat accumulation is recorded in case of T_{upper}=35°C compared to T_{upper}=30°C. The reason, as expected, is that T_{max} exceeds rarely lower upper threshold (T_{upper}=30°C) in relatively colder months, but frequently higher upper threshold (T_{upper}=35°C) in warmer months.

For a given T_{upper}, GDD values decrease as the base temperature increases. This is the direct consequence of shrinking temperature extent between T_{base} and T_{mean}. As an example, for the station Nazilli, the month October and T_{upper}= 30°C, GDD values are 597.1, 442.5, 381.7, 294.1 and 177.5°C for T_{base} values of 0, 5, 7, 10 and 15°C, respectively. This decrease is more notable in relatively colder months, particularly in March in which there is up to ten-fold decrease. For example, in Kuşadası and for T_{upper}=35°C, GDD is 400.2°C for T_{base}=0°C, but 44.3°C for T_{base}=15°C. However, in summer months, particularly in July or August, the decrease is about 50%.

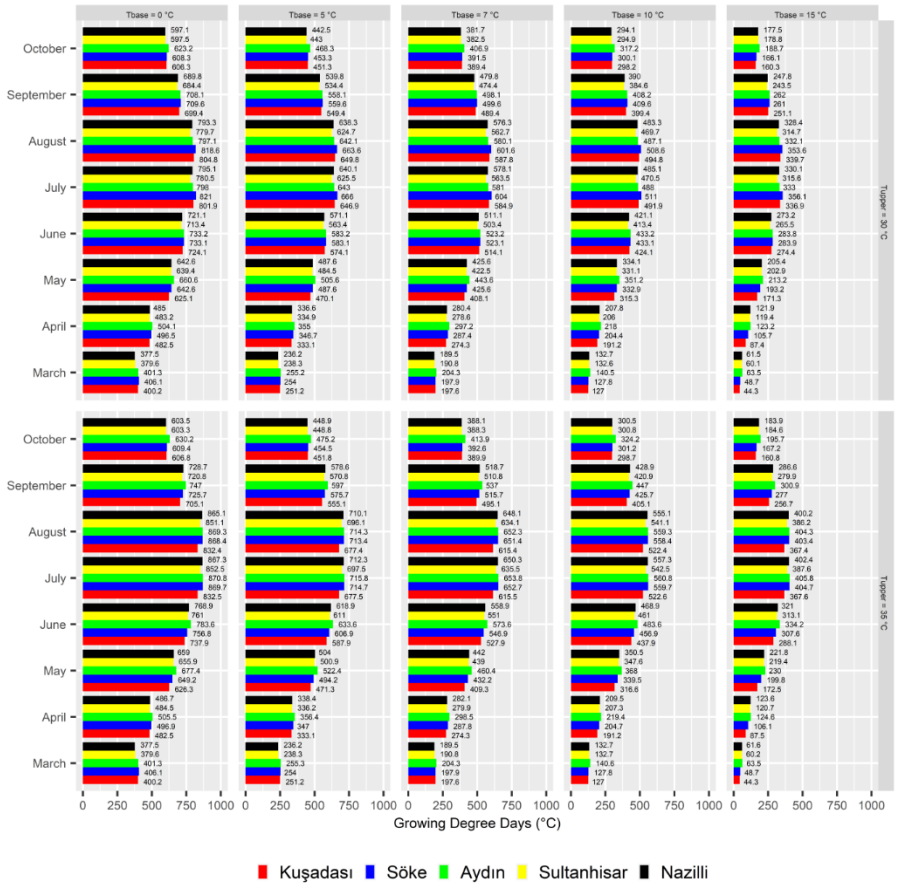

Figure 2. Monthly GDD values by month and station

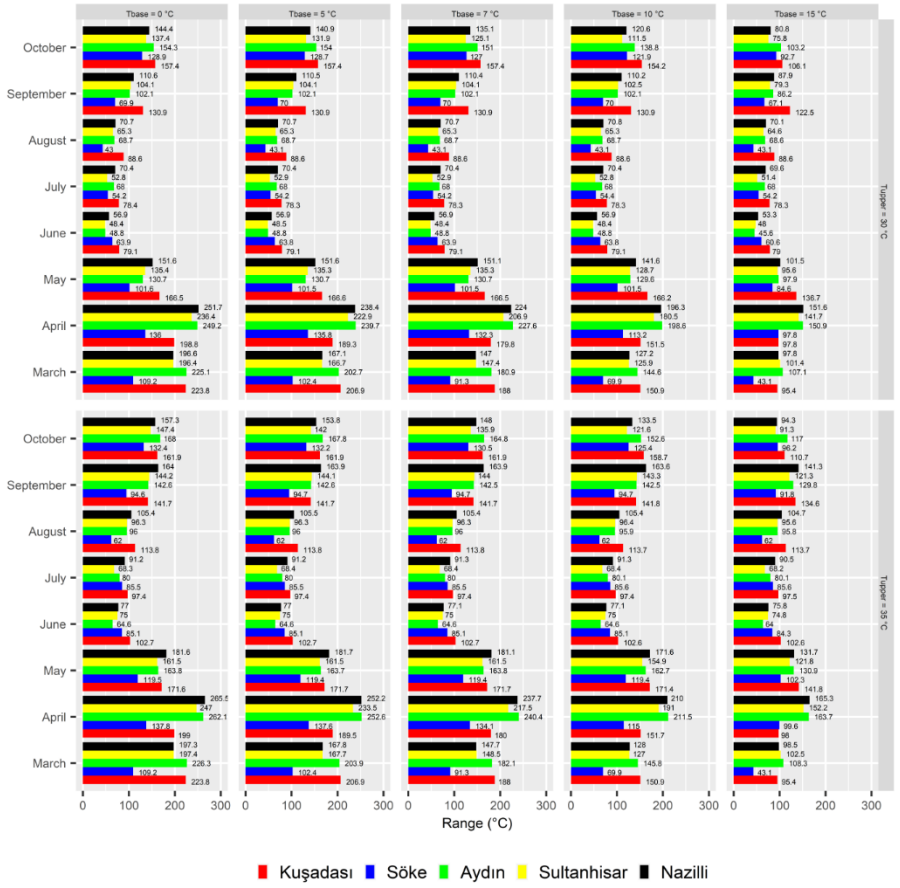

Figure 3. Ranges of monthly GDD values

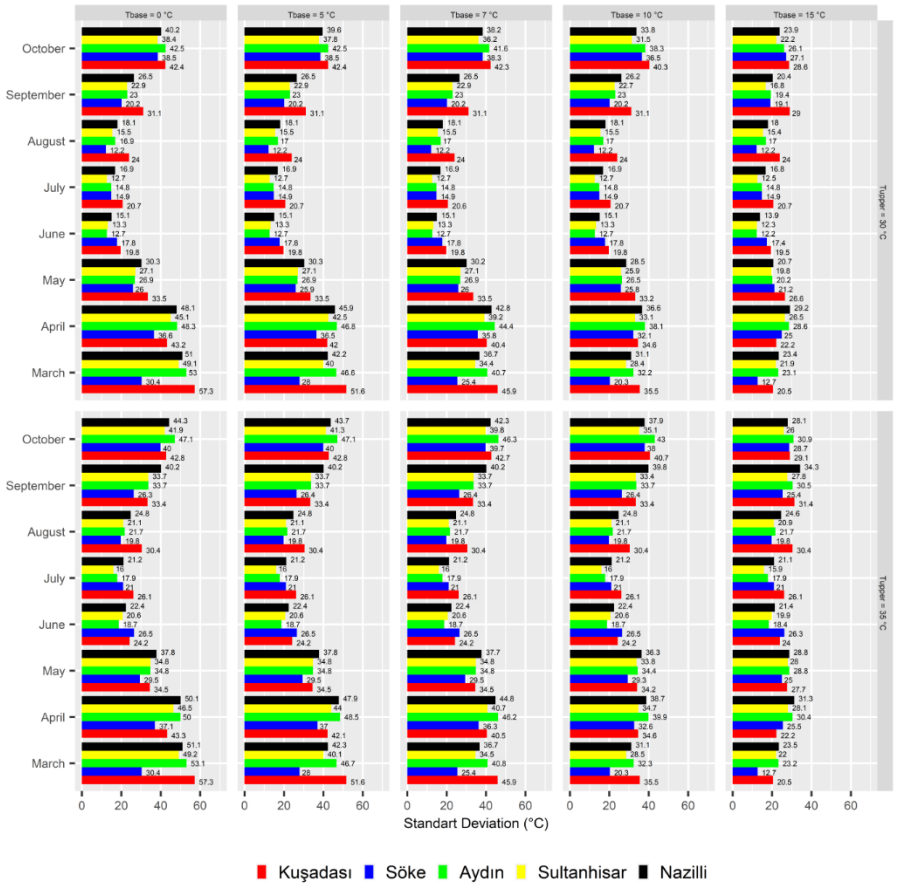

Figure 4. Standart deviations of monthly GDD values

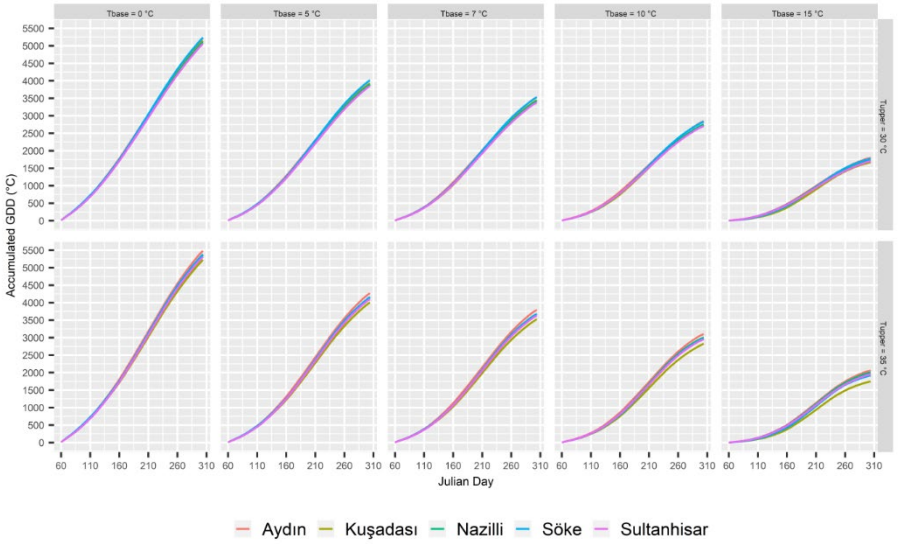

Figure 5. Accumulated GDD from March 1st (Julian day 60) through October 31st (Julian day 304)

For given T_{base}, station and month, GDD is higher for the case with higher T_{upper} than that the case with lower T_{upper}, particularly in warmer months, due to the fact that the temperature interval between T_{base} and T_{upper} is higher in the case that the higher T_{upper} (i.e., 35°C) is used. As an example, for T_{base}=0°C, August and Nazilli, GDD values are 793.3 and 865.1 C for T_{upper} of 30 and 35°C, respectively. However, this may not be the case in colder months, yet they are equal or differ very slightly, because T_{max} exceeding T_{upper} (30 or 35°C, in this study) does not occur in these months. For again Nazilli and T_{base}=0°C, GDD (377.5°C) is the same in March for both T_{upper}=30°C and T_{upper}=35°C. On the other hand, in April, which is warmer than March, the corresponding values in Nazilli for T_{base}=0°C are 485 and 486.7°C, representing a slight increase between them.

Variabilities of GDD values over the study period can be evaluated through their ranges and standart deviations, as shown in Figures 3 and 4, respectively. There exist in general decreasing tendencies from spring months toward

mid-summer, and then increasing tendencies afterwards. In other words, the highest ranges and standart deviations are observed in spring or early autumn months, which are relatively colder, while the lowest ones occur in summer months. This pattern is almost valid at all stations for all T_{base} and T_{upper} combinations, and can be easily discernable by the lengths of bars in which the corresponding range and SD values are located at the tip of bars. The highest range and SD values are observed in spring months, particularly in March or April. However, the lowest ones exist in summer months. Those in September and October lie in between those of spring and summer months. This pattern of monthly variability in range and SD values is just opposite of averages. While spring months have the lowest averages, they have the highest range and SD values. Similarly, summer months have the highest averages and the lowest range and SD values. All these results imply that uncertainty is the highest in spring months, and that larger departures from averages can be expected in these months. Failure in an attempt to estimate crop growth in early stages in spring is more likely. Conversely, this is not the case in summer months.

Figure 5 depicts average accumulated GDDs from March 1st through October 31st at all stations for all T_{base} and T_{upper} combinations. X-axes in each panel represent day from Julian day 60 (March 1st) to Julian day 304 (October 31st), ignoring leap day (February 29th). In each panel, all curves are S-like. All lines are steeper in mid-season (i.e., Julian day 152 through Julian day 243, or June through August) than in begining or end. This indicates more heat accumulation in mid-season due to higher temperatures. For a given T_{upper}, accumulated GDD decreases as T_{base} increases. This pattern, as an example, can be shown by tracking the values of Aydın for T_{upper}= 30°C during the whole study period from March 1st to October 21st. The accumulated GDDs in Aydın for T_{upper}=30°C are 5226.6, 4011.5, 3535.3, 2844.2 and 1800.3°C for T_{base} values of 0, 5, 7, 10 and 15°C, respectively.

A few studies were conducted to determine heat requirements of various major crops in Aydın. Serter (2003) grew six corn varieties as main and second crop in 2001 and 2002, and determined accumulated GDD values during specific phenophases and whole growth period. For example, GDD for whole growth period changed for from 1042°C to 1869°C depending on year, variety and planting time. Serter (2003) assumed 10°C as T_{base} and 30°C as T_{upper}, and replaced T_{min} by 10°C if T_{min} is less than T_{base}, and T_{max} by 30°C if T_{max} is greater than T_{upper}. Özkan and Kaynak (2009) determined heat accumulations of four cotton varieties during specific phenophases and whole growth period in 1997, 1998 and 1999 in Aydın, assuming 15.6°C as T_{base}. For whole growth period, accumulated GDD values ranged from 1310°C to 1386°C. A farmer or agricultural practitioner can estimate timing of a specific phenophase or whole growth period for corn or cotton by using the results of this study together with that found by Serter (2003), and Özkan and Kaynak (2009) in Aydın, or for any other crop provided that its heat requirements and the threshold temperatures are available.

Conclusions

This study presents average GDD values for various base and upper threshold temperature combinations, calculated over the latest climatic normal period from 1991 to 2020 at five sites in Aydın, Türkiye, to determine the time a specific growth phase of a crop is attained. Monthly averages show a pattern that increases from March to July or August, then decreases thereafter till October. Range and standart deviation show approximately an opposite pattern, suggesting higher uncertainity in relatively colder months. Therefore, more caution is needed when incorporating GDDs in month with higher range and SD values into heat accumulation.

Declarations

Conflict of Interest

The author declares no conflict of interest.

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Determination of Germination and Emergence Performance of Hemp (*Cannabis sativa* L.) Seeds at Different Maturity Stages

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Seed maturity

ABSTRACT

Seed maturation in hemp is not homogeneous, and the harvest is done when the seeds are 70-80% mature. This study was carried out to determine the germination and emergence performance of hemp (*Cannabis sativa* L.) seeds at different maturation stages. Mature, semi-mature and immature seeds were used as material in the study. The study was carried out as two separate experiments, germination and emergence. The germination test was carried out in petri dishes and the emergence test in viols. Both experiments were carried out according to the randomized complete block design with 3 replications. Germination rate (%), shoot and root length (mm), shoot and root fresh weight (mg plant^{-1}) and shoot and root dry weight (mg plant^{-1}) parameters were investigated in the germination study. In the emergence study, the emergence rate (%), seedling and root length (mm), seedling and root fresh weight (mg plant^{-1}), and seedling and root dry weight (mg plant^{-1}) values were examined. In the germination study, semi-mature seeds germinated but did not develop. Therefore, no data could be obtained from other parameters except germination rate. In germination study, germination rate varied between 6.67 and 84.67%, shoot length 27.2-38 mm, root length 39.4-50.8 mm, shoot fresh weight 30.66-49.89 mg plant^{-1}, root fresh weight 4.32-7.69 mg plant^{-1}, shoot dry weight 3.25-7.99 mg plant^{-1}, root dry weight 0.68-2.03 mg plant^{-1}. In the emergence study, emergence rate ranged between 5.18-82.69%, shoot length 68-136.4 mm, root length 37.4-69.6 mm, shoot fresh weight 60.33-154.80 mg plant^{-1}, root fresh weight 27.30-46.73 mg plant^{-1}, shoot dry weight 3.97-10.24 mg plant^{-1}, root dry weight 2.61-5.43 mg plant^{-1}. In both experiments, the highest values obtained from all the examined traits were obtained from mature seeds. In both studies, the highest values were obtained from mature seeds for all traits examined. Semi-mature and immature seeds gave similar results in terms of the traits examined.

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Introduction

Hemp (*Cannabis sativa* L.) is an annual, dioecious, and cross-pollinated plant that humans have cultivated since ancient times (Yilmaz et al., 2023). Hemp, as a fiber plant, has been used by humans mainly as a source of fiber, but its seeds and oil obtained from the plant extracts have also found widespread use. In this sense, it has been reported that different parts of hemp can be used in the medical, automotive and food sectors, especially in the textile industry (Pounds, 2010; Antonisomy et al., 2015).

In a successful production, obtaining the desired plant density and high yield depends on the fast, uniform and complete germination and emergence of the sown seeds (Elkoca, 2007). Hemp can be cultivated at varying plant densities depending on whether it is grown for seed or fiber production (Benevenute et al., 2022). Plant density in hemp affects yield and yield criteria by enabling the plant to benefit from light, water and nutrients effectively (Westerhuis, 2016; Tang et al., 2017; Yazici et al., 2020). Studies on the effect of plant density on fiber and seed yield in hemp have been conducted on a large scale such as 90 (Ranalli, 1999), 150-225 (Townshend & Boleyn, 2008) and 300 plants/m^2 (Hall et al., 2014). However, even if the sowing is done at a level to obtain the appropriate plant density, the chance of obtaining the desired quality fiber and seed decreases if uniform germination does not occur due to environmental or seed-borne factors.

In plant production, the first step of cultivation is sowing the seed under suitable conditions and ensuring its emergence (Karakurt et al., 2010). However, germination is affected by environmental factors such as temperature, humidity, and soil salinity on one hand (Karakurt et al., 2010), and lack of uniformity in genetic structure, seed

maturity, and seed size, on the other hand (McDonald, 2000; Karakurt et al., 2010). Therefore, the rate of germination and emergence decreases and the desired plant density is not achieved (Elkoca, 2007).

Seed maturation in hemp is not homogeneous, it occurs from the bottom up in the plant. It is risky to wait for all the seeds to mature for harvest, as early maturing seeds tend to shed (Madia et al., 1998; Marzocchi & Caboni, 2020). It has been observed that even in the harvest made when the seeds are 70-80% mature in hemp, some seeds cannot fully mature (Yılmaz et al., 2021). For this reason, this study aimed to determine the germination and emergence parameters of hemp seeds at different maturity levels.

Materials and Methods

Materials

This study was carried out in Yozgat Bozok University, Faculty of Agriculture laboratories in two different ways, as germination and emergence trials in 2022. The seeds used in this study were obtained from the studies carried out for seed production in 2021 by Yılmaz et al., (2021) in Yozgat Bozok University, Institute of Hemp Research, Department of Agriculture and Food. In the study, seeds belonging to the Narlısaray hemp population were used as material. Seeds were divided into 3 different groups according to their maturity, and the characteristics of each group are given in Table 1 and Figure 1.

Methods

The germination study was carried out in the germination chamber, using petri dishes (100 × 20 mm). The study was carried out according to a randomized complete block design with 3 replications and a total of 50 seeds were used for one replication of each treatment. The selected seeds were first sterilized with 5% Sodium Hypochlorite for 5 minutes, then placed between blotting paper (as a germination medium) in petri dishes. The Petri dishes were incubated at 20°C (Suriyong et al., 2015) and 8 h light, 16 h dark cycle (Geneve et al., 2022) in germination chamber. The seeds in the germination medium were monitored and the embryonic roots emerging from the testa were considered germinated when they reached 1 mm and the germinated seeds were counted daily for seven days (Suriyong et al., 2015; Hu et al., 2018). At the end of the germination study, germination rate (%), shoot and root length (mm), shoot and root fresh weight (mg plant^{-1}) and shoot and root dry weight (mg plant^{-1}) were measured.

The emergence study was carried out in the climatic chamber, in peat-filled viols (50x50 mm), with 45 seeds in each viols according to a randomized complete block design with 3 replications. The seeds were sowed at a depth of 4 cm and the ambient temperature was adjusted to 18-23 °C (day and night), and the humidity was constantly controlled. The emergence study was terminated on the 21st day and, emergence rate (%), seedling and root length (mm), seedling and root fresh weight (mg plant-1), and seedling and root dry weight (mg plant-1) were measured.

Statistical Analysis

The data obtained from both studies were analyzed with the JMP statistical package program according to the randomized complete block design (RCBD), and mean values were compared according to LSD.

Figure 1. Hemp seeds at different maturity levels (A: Mature, B: Semi-mature C: Immature).

Table 1. Information on hemp seeds at different maturity stage

Seed group	Seed characteristics
Mature seeds	Seeds that have completed their physiological maturity, have reached the ideal seed size and seed coat hardness, have completed formation of ideal testa (seed coat) color (brown color) and have a moisture content of around 10% (±2). The average 1000 seed weight is 17.04 g and the width and length dimensions of the seeds are 3.24-4.81 mm.
Semi-mature seeds	Seeds that although have completed the green-yellow maturation period, have not completed their physiological maturity. The testa (seed coat) color is between green and light brown, the seed coat has not reached the ideal hardness, and the moisture content is around 15% (± 2%). The average 1000 seed weight is 7.01 g and the width and length dimensions of the seeds are 2.76-4.47 mm.
Immature seeds	Seeds that are still in the green-yellow maturation period and have a green color testa (seed coat). These seeds have not reached the ideal seed coat hardness and seed size, and have a moisture content of around 20% (± 2). The average 1000 seed weight is 6.89 g, and the width and length dimensions of the seeds are 1.97-3.42 mm.

Table 2. Variance analysis results (F values) and significance levels of the germination study of hemp seeds at different maturity stage

SV	df	GR	SL	RL	FSW	FRW	DSW	DRW
Maturity stage	2	394.57*	610.45*	647.56*	832.12*	124.47*	1311.19*	1391.27*
Replication	2	0.00	0.70	0.39	0.01	1.56	0.01	3.15
CV		10.59	6.31	6.09	5.63	14.95	5.13	5.30

SV: source of variation, df: degree of freedom, GR: germination rate (%), SL: shoot length (mm), RL: root length (mm), FSW: fresh shoot weight (mg plant^{-1}), FRW: fresh root weight (mg plant^{-1}), DSW: dry shoot weight (mg plant^{-1}), DRW: dry root weight (mg plant^{-1}). *: $p<0.05$

Table 3. Average germination values of hemp seeds at different maturity stages

MS	GR	SL	RL	FSW	FRW	DSW	DRW
Mature seeds	84.67a	38.0a	50.8a	49.89a	7.69a	7.99a	2.03a
Immature seeds	14.67b	27.2b	39.4b	30.66b	4.32b	3.25b	0.68b
Semi-mature seeds	6.67b	-	-	-	-	-	-
LSD Value	8.48	3.11	4.07	3.42	1.36	0.44	0.11

MS: maturidy stage, GR: germination rate (%), SL: shoot length (mm), RL: root length (mm), FSW: fresh shoot weight (mg plant^{-1}), FRW: fresh root weight (mg plant^{-1}), DSW: dry shoot weight (mg plant^{-1}), DRW: dry root weight (mg plant^{-1}). -: Data could not be obtained because root and shoot formation after germination was not possible.

Table 4. Variance analysis results (F values) and significance levels of the emergence study of hemp seeds at different maturity stage

SV	df	ER	SL	RL	SFW	RFW	SDW	RDW
Maturity stage	2	1005.13*	589.06*	93.15*	304.85*	69.02*	325.98*	69.37*
Replication	2	0.70	0.19	0.08	0.68	0.19	0.86	0.26
CV		6.90	2.93	5.66	5.83	6.81	5.60	8.99

SV: source of variation, df: degree of freedom, ER: emerence rate (%), SL: seedling length (mm), RL: root length (mm), SFW: seedling fresh weight (mg plant^{-1}), RFW: root fresh weight (mg plant^{-1}), SDW: seedling dry weight (mg plant^{-1}), RDW: root dry weight (mg plant^{-1}). *: $p<0.05$

Results and Discussion

Germination

The variance analysis results of the data obtained from the germination study are given in Table 2. As shown in Table 2, statistically significant differences ($p< 0.05$) were determined in all parameters examined among hemp seeds of different maturity.

The highest germination rate (GR) (84.67%) in hemp seeds of different maturity was obtained from mature seeds, while the lowest value (6.67%) was obtained from semi-mature seeds. Mature seeds exhibited high values in shoot length (SL) (38.00 mm) and root length (RL) (50.80 mm), while immature seeds had the low values (27.2 and 39.4 mm, respectively). Fresh shoot weight (FSW) obtained from the germination study ranged from 30.66 to 49.89 mg plant^{-1}, and the fresh root weight (FRW) ranged from 4.32 to 7.69 mg plant^{-1}. In both parameters, the high values were obtained from mature seeds, and the lower values were obtained from immature seeds. High values in dry shoot weight (DSW) and dry root weight (DRW) (7.99 and 2.03 mg plant^{-1}, respectively) were obtained from mature seeds, while immature seeds had low values (3.25 and 0.68 mg plant^{-1}, respectively) (Table 3).

Emergence

The variance analysis results of the data obtained from the emergence study are given in Table 4. Based on the results it was determined that there were statistical differences ($p<0.05$) among the hemp seeds of different maturity in terms of all parameters examined.

In the emergence tests with hemp seeds of different maturity, the highest emergence rate (ER) (82.96%) was obtained from mature seeds. The lowest ER (5.18%) was obtained from semi-mature seeds, while this rate was determined as 13.33% for immature seeds. In the emergence study, the longest SL and RL were obtained from mature seeds with 136.4 and 69.6 mm, respectively, while semi-mature seeds had the lowest values (68.0 and 37.4 mm, respectively). While the highest value in terms of SFW (154.8 mg plant^{-1}) was obtained from mature seeds, this value was determined as 61.57 and 60.33 mg plant^{-1} for immature and semi-mature seeds, respectively. In terms of RFW, mature seeds reached the highest value with 46.73 mg plant^{-1}, the lowest values were 27.76 mg plant^{-1} for immature seeds and 27.30 mg plant^{-1} for semi-mature seeds. The SDW obtained from the emergence study ranged from 3.97-10.24 mg plant^{-1}, and the RDW was between 2.61-5.43 mg plant^{-1}. The highest values in both SDW and RDW (10.24 and 5.43 mg plant^{-1}, respectively) were obtained from mature seeds (Table 5).

In this study, mature seeds reached the highest values in terms of all parameters examined in both germination and emergence experiments. The effect of seed maturity on germination and vigor has been studied on many plants. It has been reported that maximum germination in most plants occurs when the seeds reach maximum dry weight, which is defined as physiological maturity (Samarah & Mullen, 2004). In most seeds, the transition from the developmental stage (in which dry matter and nutrient accumulation are complete) to a germination/growth-only stage is necessary for seed maturation and ideal germination. Although immature embryos have a certain germination capacity, they often cause abnormal seedling formation because the necessary developmental metabolism cannot be completed (Kermode, 1990; Rao et al., 2005).

Table 5. Average values of emergence study of hemp seeds at different maturity stage

MS	ER	SL	RL	SFW	RFW	SDW	RDW
Mature seeds	82.96a	136.4a	69.6a	154.80a	46.73a	10.24a	5.43a
Immature seeds	13.33b	73.4b	48.6b	61.57b	27.76b	4.14b	2.84b
Semi-mature seeds	5.18c	68.0b	37.4c	60.33b	27.30b	3.97b	2.61b
LSD Value	5.29	6.15	6.65	12.19	5.24	0.78	0.74

MS: maturidy stage, ER: emerence rate (%), SL: seedling length (mm), RL: root length (mm), SFW: seedling fresh weight (mg plant^{-1}), RFW: root fresh weight (mg plant^{-1}), SDW: seedling dry weight (mg plant^{-1}), RDW: root dry weight (mg plant^{-1}).

Storing hemp seeds in a sheltered but uncontrolled environment for 2 years reduces the germination rate to about 70-80% rather quickly and it is not recommended to use these seeds in sowing. In commercial applications, 85-90% of minimum germination of hemp seeds was recommended (Bósca & Karus, 1998; Small & Brookes, 2012). While the germination rate we obtained from mature seeds in our study (84.67%) matched the germination rates recommended for commercial applications, the germination rates obtained from immature or semi-mature seeds were far below these values (14.67% and 6.67%, respectively).

Harvest time significantly affects the thousand seed weight (Gu et al., 2017). It is reported that the thousand seed weight of hemp seeds varies between 12-30 g (İncekara, 1979; Gönen, 2009; Gün, 2019; Dumanoğlu et al., 2021). While the thousand seed weights of the mature seeds we used in this study (17.04 g) are among the values reported for hemp, the thousand seed weights of the immature and semi-mature seeds are below these values (6.89 and 7.01 g, respectively). İncekara (1979) reported that hemp seeds are 4-6 mm in length and 3-3.5 mm in width, while Gün (2019) reported that they are 4 mm long and 3 mm wide. While the sizes of mature (length 4.81 mm, width 3.24 mm) and semi-mature (length 4.47 mm, width 2.74 mm) seeds we used in this study were like the dimensions reported for hemp, the dimensions of immature seeds were behind these values (length 3.42 mm, width 1.97 mm). Although the sizes of the mature and semi-mature seeds we used in this study are similar, there are differences in thousand seed weights. This situation shows that embryo and endosperm development in semi-mature seeds could not reach a sufficient level. According to the results we obtained from study, the values obtained from semi-mature seeds were similar to the values obtained from immature seeds. Seed size is an important factor affecting germination. Nutrients hidden in plant seeds are used for sprouting and also affect the growth and development of the plant (Dunlap & Barnett, 1983; Ambika et al., 2014; Moon et al., 2020). Moon et al., (2020) reported that small-sized hemp seeds are not suitable for germination, so seed screening is important to separate small seeds.

In many cultivars, seeds can germinate a few days after zygote formation. In this case, germination means a protrusion of the primary root, not a normal seedling formation. Because histo-differentiation is incomplete and nutrient reserve accumulation in the seed is still in its beginning at this stage. The germination described here leads to the production of seedlings with low viability (Leishman, 2001). Theoretically, it is possible to state that the germination rate of seeds increases with maturation and germination reaches its maximum when the seeds reach maximum dry weight (Bareke, 2018).

Harvesting seeds at different maturation periods can change germination rates (Miyajima, 1997; Gu et al., 2017; Yağız, 2019). The physiologically mature seeds have a positive effect on storability and germination, and they also perform better in field conditions (Doijode, 1988; Pallais et al., 1989; Rao et al., 2005). Seed maturity affects not only seed germination but also seedling development. In addition, immature seeds are more susceptible to diseases and adverse environmental conditions (Singh & Singh, 1992; Negi & Todaria, 1995).

Rao et al., (2005) reported that seed viability, evaluated based on germination rate and seedling length in tomato plants, was at the highest level in mature seeds compared to immature and over-mature seeds, while the maximum germination rate (86.5 %) was obtained from mature seeds. Zecevic et al., (2006) reported that mature seeds of wheat plants significantly affect shoot and root dry matter content, and the amount of both dry matters increases from the milk maturity stage to the full maturity stage of the seeds. The low amount of dry matter in seedlings obtained from seeds that have not reached full maturity is due to the low nutrient reserves in endosperm and seed weight (Zecevic et al., 2006). In this context, it has been reported that growth is weak in immature seeds with low nutrient content, whereas mature seeds with high nutrient content allow stronger seedling growth and higher dry matter content (Babayan, 1960; Boyd et al., 1971; Pucaric & Ujevic, 1986; Zecevic et al., 2006).

Conclusion

In this study, the germination and emergence performances of hemp seeds at different maturity stages were evaluated, the highest values in terms of all parameters examined were obtained from mature seeds. The use of seeds that are not suitable for hemp cultivation will cause the desired density not to be achieved, thus reducing the yield and quality. In this sense, impurities and seeds that have not reached full maturity should be eliminated from seeds to be used in hemp cultivation. In addition, it is necessary to attach importance to the production of seeds suitable for hemp cultivation, to take necessary steps in this regard and to raise awareness of farmers who turn to hemp farming.

Declarations

Author Contribution Statement

Y.G., Y.C., G.N.D.: Concept; Y.G., Y.C., G.N.D.: Desing; Y.C., G.N.D.: Data Collection or Processing; Y.G., Y.C.: Statistical Analyses; Y.G., Y.C., G.N.D.: Literature Search; Y.G., Y.C., G.N.D.; Writing, Review and Editing.

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Conflict of Interest

We declare that there is no conflict of interest between us as the article authors.

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Dietary Supplementation of Solid-state Fermented Yellow Mealworm (*Tenebrio molitor*) Larvae Meal Enriched by *Lactobacillus sp.* in Guppy (*Poecilia reticulata*)

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ABSTRACT

The current study examined the dietary solid-state fermented yellow mealworm (*Tenebrio molitor*) larvae meal inclusion on growth performance, gut microbiota, body composition, liver and intestinal histology and histomorphometric parameters in the guppy (*Poecilia reticulata*) for 84 days. Guppies were fed diets included with no supplementation (C); 4 g/kg yellow mealworm larva meal (G1), 4 g/kg solid-state fermented with *Lactobacillus brevis* yellow mealworm larvae meal (G2), 4 g/kg solid-state fermented with *Lactobacillus plantarum* yellow mealworm larvae meal (G3), the combination of 2 g/kg solid-state fermented with *L. brevis* plus 2 g/kg solid-state fermented with *L. plantarum* yellow mealworm larvae meal (G4). For female guppies, the growth performance of the G4 group clearly differed from all groups with the synergistic effect of solid-state fermented with *L. plantarum* plus *L. brevis*. In male guppies, G3 and G4 groups showed the highest growth performance values among all groups. The intestinal microbiota of guppies was clearly varied with supplementation groups. Fusobacteria was the most abundant phylum in C, G1, G2 and G3 groups. However, Proteobacteria showed the most intensity in the G4 group. Intestinal villus height, width and surface area were positively affected in solid-state fermented yellow mealworm larvae meal supplementation groups, reaching higher values in G3 and G4 groups. In conclusion, solid-state fermented yellow mealworm larvae meal via 2 g/kg *L. plantarum* plus 2 g/kg *L. brevis* can improve growth performance by modulating the gut microbiota of guppies.

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Introduction

Although most of the global aquaculture production is devoted to food products, ornamental fish production continues to expand as one of many countries' crucial products of the aquaculture industry (Rahmati-Holasoo et al., 2022). The ornamental fish sector mostly depends on aquaculture in the supply of feed raw materials. In recent years, the rapid growth of aquaculture production has caused concern in the feed industry due to limited resources (Gu et al., 2022). Moreover, the importance of improving feed formulations with functional ingredients has emerged as one of the most critical factors for all aspects of the sustainability of the sector (Ghamkhar & Hicks, 2020). At this point, developing production strategies that will promote the healthy growth of cultured fish in the diet is expressed as an effective solution for the efficient use of resources (Rohani et al., 2021). As in all aquaculture production areas, approaches to the sustainable use of feed resources in the ornamental fish sector draw attention (Sultana et al., 2022). The aquarium hobby has gained value as a new activity for most people who stay home during the coronavirus pandemic (Hood et al., 2021). Also, the pandemic has revealed that countries should produce some aquarium species with local possibilities and the need for feed additives to increase the diet quality. Feed additives can positively affect the health of the fish's digestive system (Dawood et al., 2018). In recent years, regulating the gut microbiota in fish's digestive system has been among the priority studies to improve healthy growth in cultured species (Tan et al., 2019; Terova et al., 2019; Deng et al., 2022). Common methods to regulate the gut microbial community include enrichment feed formulations with functional feed additives (FFAs) such as

probiotics, prebiotics, and synbiotics. FFAs are a promising alternative growth promoter for fish performance (Benzertiha et al., 2020). In addition, previous studies emphasized that solid-state fermented feed additives improved the gut microbiota and could be potentially functional for fish species (Zhang et al., 2021; Yang et al., 2022). Also, feed efficiency and growth performance can be increased by reducing feed costs in the aquatic environment with solid-state fermented feed additives (Bowyer et al., 2020; Davies et al., 2021). Compared to conventional animal and plant-derived feed ingredients, insect meals (IM) as a novel feed ingredient have advantages with their ability to efficiently utilize organic waste, small ecological footprints and nutritional values (Rumpold & Schlüter, 2013; Feng et al., 2019). Dried mealworm larvae meal solid-state fermented with probiotics as an alternative feed additive to growth promoters in animal diets has been came up recently (Islam & Yang, 2017). Thus, IM can contribute to reducing environmental concerns (Quang Tran et al., 2022). Seven species of insect meal, including yellow mealworm (TM) (*Tenebrio molitor*) have been approved by the European Union (EU) for use in aquatic feeds (European Commission, 2017). The use of yellow mealworm larvae meal (TML) in aquaculture has recently drawn attention (Feng et al., 2019).

Besides its nutritional quality (protein content, digestibility, flavor), TML can be a functional feed additive (Hong et al., 2020). However, the high chitin levels (more chitin levels than 1.60 %) in TML may negatively affect feed intake and protein availability and thereby worsen growth performance in fish (Ge et al., 2022). Some studies pointed out that one possible strategy to improve the nutritional value and to create functional feed additives of unusual feed ingredients such TML and black soldier fly larvae for domestic animals is solid state fermentation (SSF) (Islam & Yang, 2017; Mulyono et al., 2019; Luparelli et al., 2022). Solid-state fermented feed ingredients are arranged for balanced nutritive characteristics, using probiotics and water under aerobic or anaerobic environments (Zhang et al., 2021). Among the probiotic bacteria species, *Lactobacilli* (Lactic acid bacteria, LAB) is the most used for TML solid-state fermentation (Islam & Yang 2017).

In poultry science, some researchers claimed that the addition of small amounts of TM full-fat meal as an antibacterial feed additive to broiler diet in an *in vivo* study could modulate the microbiota composition of the gastrointestinal tract and improve growth indices (Benzertiha et al., 2019; 2020; Józefiak et al., 2020). However, there is no knowledge about including defatted TML (DTML) solid-state fermented with probiotic bacteria as a functional feed additive to diet in aquaculture, including aquarium fish. In this context, understanding the effects of the DTML solid-state fermented with probiotics as a feed additive on the gut microbiome using new approaches may contribute to elucidating their role in the healthy growth of fish.

The aquarium sector is subject to ethical debates in terms of including organisms obtained from nature (Tlusty et al., 2013). The species cultured in the aquarium must be ensured from aquaculture in a way that does not have a detrimental effect on natural resources (Evers et al., 2019). In accordance with all these approaches, one of the species that attracts attention in the ornamental fish sector is the guppies (Kowalska et al., 2022). Guppies have become the most popular ornamental fish preferred among hobbyists due to their adaptability to changing environmental and ecological conditions, easily raised and fast reproduced cycles. In addition, guppies are utilized as a model organism in studies involving many fields, such as ecology, evolution, behaviour and feeding experiments (Ahmadniaye Motlagh et al., 2020; Sultana et al., 2022). With these versatile characteristics, guppies have an ever-increasing demand in the industry.

Therefore, we hypothesized that DTML fermented with *Lactobacillus brevis* and *L. plantarum* may modulate intestinal microbiota and histomorphometric parameters, improving guppy growth performance; in this study, we report the effects of fermented and non-fermented DTML on growth performance, intestinal microbiota, and histological parameters of the intestine and liver, and body composition in guppies.

Material and Methods

Ethics Statement

The research followed the Animal Experiments Local Ethics Committee guidelines at Ankara University and obtained approval under permission number 2021-11-92.

Experimental Design

The study was performed in the Fisheries Research and Application Unit (FRAU) of the Agricultural Faculty of Ankara University. Total 320 healthy guppies (160 males and 160 females, average body weight of 0.15±0.01 g) in the FRAU were used for the experiment and randomly distributed in 20 fiberglass tanks (45 L) with four replicates of 16 fish each (8 males and 8 females). Four yellow mealworm larva meal diets were formulated to include two probiotics for comparative examination. The yellow mealworm larva meal with fermented and non- fermented was incorporated into the diet as follows: (C) involved with no supplementation; (G1) supplemented with 4 g/kg DTML; (G2) supplemented with 4 g/kg DTML fermented with *L. brevis*; (G3) supplemented with 4 g/kg DTML fermented with *L. plantarum*; (G4) supplemented with combination of 2 g/kg DTML fermented with *L. brevis* plus with 2 g/kg DTML fermented with *L. plantarum.* Physicochemical water quality parameters such as dissolved oxygen (7.51 ±0.06 ppm), temperature (25.27 ±0.52°C, YSI PRO 20, Yellow Springs Instruments) and pH (6.85± 0.11, YSI EcoSense pH10 A, Yellow Springs Instruments) were maintained according to the standard culture conditions of *P. reticulata* (Zdanovich, 2017). Daily 10% water exchange were performed. Continuous aeration and filtration were applied to the tanks via filter pipe. Feeding was applied *ad libitum* twice daily (08:00 AM and 4:00 PM) for 84 days. Natural photoperiod (10L:14D) was adjusted during the experiment.

Preparation of Experimental Diets

TM was acquired from a commercial supplier located in Ankara, Turkey, and was fed with wheat, wheat bran, and carrot. Before processing, TM underwent freeze-drying overnight to eliminate moisture without prior

starvation. The dried TM were ground into the meal with the miller. TM produced from the larval stage of yellow mealworms was full fat. Then, the protein content of TML in the present study was increased by the chemical defatting process since protein may be utilized as substrates by microorganisms for solid-state fermentation (Son et al., 2021). Optimized extraction conditions (petroleum ether to TML ratio of 3:1 L/kg, 60°C for 4 h) with a soxhelet device were applied for defatting of freeze-dried TML. Following the process of defatting, drying of TML was performed at 40°C for 3 h. This process reduced the high-fat content of TML (from 23% to 6.6%) and increased the crude protein content (from 44% to 76.2%).

The protein content, determined based on acid detergent fiber (ADF) according to AOAC (2003), was utilized to calculate the chitin content in defatted TML (DTML) using the procedure outlined by Finke (2007) in the following manner: chitin (%)= ash-free ADF (%)-ADF linked protein (%). The amount of chitin of DTML was 4.2 %. The composition of DTML is shown in Table 1.

For the solid-state fermentation of DTML, two probiotic bacteria (*Lactobacillus plantarum* and *Lactobacillus brevis*) and *Saccharomyces cerevisiae* (baker's yeast) were used. The *Lactobacillus plantarum* strain was isolated from Çeçil cheese, while the *Lactobacillus brevis* strain was isolated from cheddar cheese. *Saccharomyces cerevisiae* (baker's yeast) was produced from sugar beet molasses. *Saccharomyces cerevisiae* during fermentation enhances the viability and growth of lactic acid bacteria (LAB), since it provides some nutrients, such as amino acids and vitamins to LAB (Menezes et al., 2018; Shi et al., 2020). The probiotics used in fermentation, which have chitinase activity, were obtained from Neslihan Dikbaş Microorganism Culture Collection at the Agricultural Biotechnology Laboratories of Ataturk University. Chitinase enzyme activities of the probiotics were analysed in Agricultural Biotechnology Laboratory of Ataturk University (Senol et al., 2014). Chitinase enzyme activity was measured using a colloidal chitin substrate. After adding the substrate to the enzyme solution medium, it was incubated at 37°C for 30 minutes to allow the reaction to occur. Subsequently, staining solutions were added to the reaction mixture, which was then left to stand at 80°C for 10 minutes. Finally, the activity was determined by measuring the absorbance change at 540 nm with a spectrophotometer (PG-T80 Instrument UV–VIS Spectrophotometer) against a blank sample prepared with distilled water. The chitinase enzyme activities of *L. plantarum* and *L. brevis* were found as 15.00 U/L and 11.36 U/L, respectively. The method of Islam & Yang, (2017) was modified in Semi-Solid Phase Fermenter for fermentation of DTML with two different probiotic bacteria in the laboratory of Isparta University of Applied Sciences, Agricultural Faculty, Department of Animal Science.

During the fermentation process of DTML, probiotics were cultivated on solid media consisting of distiller's dried grains with solubles (DDGS) and defatted rice bran. DTML, DDGS, defatted rice bran and water used for fermentation were autoclaved (at 121°C for 15 min) for sterilization. For the fermentation, a mixture including 30 % DTML, 35 % DDGS, 35 % defatted rice bran and 80 % distilled water was prepared. After DDGS, defatted rice bran, DTML and distilled water were placed in the fermenter, carbon dioxide adding was performed to create an anaerobic environment. Incubated *L. plantarum* (100 ml) was added to the medium and performed fermentation under anaerobic conditions (38ºC for 48 h). At the end of this time, *S. cerevisiae* with 1.0 % was used in the second fermentation under anaerobic conditions. Activation of *S. cerevisiae* was performed for 1h at 37ºC in 250 ml of 0.1 % peptone water (10 g yeast + 90 ml peptone water) at 38ºC. After a total of 96 hours completed, the fermented product was dried until less than 15% moisture was achieved at 32ºC for 24 h using a drying oven (Memmert GmbH + Co. KG, Beuchenbach, Germany). The same protocol was carried out for *L. brevis*. To identify microbial concentration, diluted with sterile saline (9 ml of 0.85 %) 1 g of the fermented DTML with *L. plantarum* (FDTMLP) or fermented DTML with *L. brevis* (FDTMLB) were mixed. Total mesophilic aerobic bacteria count was then performed by plating serial 10-fold dilutions in triplicate on Plate Count Agar (PCA) and incubated for 48 hours at 30°C under aerobic conditions. For the *Lactobacillus* counts, it was performed by plating serial 10-fold dilutions in triplicate on De-Man Rogosa and Sharp (MRS) agar and incubated for 5 d at 39-40°C under anaerobic conditions. Yeast and mold counts were made by plating serial 10-fold dilutions in triplicate on Dichloran Rose Bengal Chloramphenicol (DRBC) agar and incubated at 25°C for 5 d under anaerobic conditions. Following the incubation, microbial colonies immediately counted were stated as log10 CFU/g. For FDTMLP and FDTMLB, the nutrient composition and concentrations of microorganisms were presented in Table 2. The protein concentration in association with acid detergent fibre (ADF) was calculated (AOAC, 2003) and used to predict chitin level in FDTMLP and FDTMLB (Finke, 2007) as follows: chitin (%)= ash free ADF (%)-ADF linked protein (%). The chitin amounts of FDTMLP and FDTMLB were 2.74 and 2.81 %, respectively.

Table 1. The nutrients composition of DTML

Nutrient Composition (%)	
Dry Matter	95.70
Crude Protein	76.20
Crude Fat	6.60
Crude Ash	7.30
Starch	3.30
Total Sugar	0.50
Metabolisable Energy, Kcal kg^{-1}	3515

Table 2. The nutrients composition and concentrations of microorganisms in FDTMLP and FDTMLB

Item	FDTMLP	FDTMLB
Microorganisms' concentrations (log10 cfu/g)		
Total Mesophilic Aerobic Bacteria	3.92	4.29
Lactobacillus	2.99	2.45
Yeast-Mold	Not detected	No detected
Nutrient Composition (%)		
Dry Matter	92.00	89.81
Crude Protein	49.28	49.06
Crude Fat	8.14	9.40
Crude Ash	7.81	7.83
Starch	3.73	1.44
Total Sugar	0.36	0.36
Metabolizable Energy, Kcal/kg	2650	2660

Table 3. Ingredients and chemical composition of experimental diets (g kg^{-1} diet)

Ingredients (g kg^{-1})	C	G1	G2	G3	G4
Fish meal	300	300	300	300	300
Soybean meal	130	130	130	130	130
Corn gluten	140	136	136	136	136
Wheat flour	365	365	365	365	365
Fish oil	25	25	25	25	25
Vitamin and mineral premix	10	10	10	10	10
Binder	30	30	30	30	30
Supplement	0	4	4	4	4
Total	1000	1000	1000	1000	1000
Proximate Composition					
Crude protein	380.75	381.20	380.11	380.12	380.14
Crude lipid	79.65	79.67	79.79	79.73	79.75
Crude ash	42.95	43.16	43.18	43.18	43.20

Vit amounts/453 g Vitamin Premix (Vit A: 325,000 USP Units, Vit D3: 65 USP Units, Vit E: 32 USP Units, Vit K 793.65 mg, Vit B12: 10.08 mg, Riboflavin: 3.250 mg, p-Panthothenic acid: 15.600, Niacin: 19.500 mg, Cholin: 2.600 mg, Thiamine: 2.600 mg, Pridoxine Folic acid: 780 mg, Ascorbic acid: 87.100 mg Biotin: 40 mg, BHT: 2 mg, Inositol: 13. Minerals; Manganese 60 ppm, Zinc 50 ppm, Iron 40 ppm, Copper 4 ppm, Cobalt 0.5 ppm, Iodine 40 ppm, Selenium 0.4 ppm (Formulated and Packaged By Florida Aqua Farms Inc. Dade City, Florida).

Sample Collection and Growth Performance

A digital meter (with an accuracy of 0.01 g) was utilized to assess growth parameters (individual body weight of fish from each tank). After a 24-h fasting period, fish (four fish were sampled for each replicate, N = 16) were euthanized with a high dose of clove oil (50 mg/L) to determine the intestinal microbial diversity and body composition. Two fish from each replicate slaughtered were sampled for histological examination of liver and intestinal tissue. Growth parameters were evaluated separately since there was a difference in growth between male and female guppies, but other parameters were evaluated together since they were realized under the same experimental conditions for each group. Growth indices were calculated as follows:

$$WG = FBW - IBW \quad (1)$$

$$SGR = ((ln\ (FBW) - ln\ (IBW))/days) \times 100 \quad (2)$$

$$FCR = \text{Total Given Feed (g)}/WG\ (g) \quad (3)$$

$$SR = (NLE)/(NLB) \times 100 \quad (4)$$

WG : Weight gain (g/fish)
FBW: Final body weight (g)
IBW : Initial body weight (g)
SGR : Specific growth rate (SGR; %/day)
FCR : Feed conversion ratio (FCR)
SR : Survival rate (SR%)
NLE : number of live fish at the end of experiment
NLB : number of live fish at the beginning of the experiment

Intestinal Microbiota

To describe the gut microbiota, the intestinal content was collected from each fish. Samples were taken in the aseptic conditions and then gathered in sterile Eppendorf tubes. Until DNA extraction, all samples were stored at -80°C. For DNA extraction from intestinal contents, it was used the Qiagen Dneasy Blood and Tissue Kit (Spens et al., 2016). After this step, Qubit (Thermo Fisher Scientific, Waltham, MA, USA) was utilized for QC determination. For amplification, 16S Forward and 16S Forward Reverse coded 16S Universal Eubacterium primers specific to 16S rDNA V3-V4 regions were used.

Relevant primers were selected according to the Klindworth et al. (2013) protocol. A 2-step PCR process was performed in the library preparation. 25 cycles of PCR were carried out that used KAPA HiFi HotStart ReadyMix (Roche) to each sample separately for these processes. Following PCR, all samples were subjected to analysis on a 2% agarose gel to verify band presence and assess relative band densities. For measuring the library, Qubit fluorometry was used, and the library was sequenced after normalization. Illumina's 16S Metagenomic Sequencing Library Preparation document include the details of this protocol (Illumina, 2020). The SILVA project's amplicon analysis pipeline was used to process all sequence reads (SILVAngs 1.4) (Quast et al., 2013).

Identification of identical reads, clustering of the unique reads (OTUs) on a per sample basis, and classification of the reference read of each OTU were performed after these first step of quality control (dereplication). For dereplication and clustering, identity criteria of 1.00 and 0.98 were applied,

respectively, and using VSEARCH (version 2.17.0; https: //github.com/torognes/vsearch) (Rognes et al., 2016). The non-redundant version of the SILVA SSU Ref dataset (release 138.1; http://www.arb-silva.de) was employed for classification using BLASTn (2.11.0+; http://blast.ncbi.nlm.nih.gov/Blast.cgi), as outlined by Camacho et al. (2009).

All reads assigned to the respective OTU were mapped to the classification of each OTU reference read. Reads that did not have any or weak classification for which the function "(% sequence ID + % alignment coverage)/2" did not exceed 93 remained unclassified. These reads were defined as the "No Relative" meta group (Ondov et al., 2011).

Histological Analysis

Fish were deeply anaesthetized with clove oil (50.0 mg/L). The liver and intestinal tissues of the slaughtered fish were removed and placed in labeled histological tissue processing cassettes, and the tissues in the cassettes were fixed in 10% formaldehyde using the standard histological methodology. Tissues were embedded in paraffin blocks for histological examination. Sections (5 µ, Shandon AS-325 retraction microtome) were mounted on marked slides before staining with Mayers Haematoxilen and Eosine. Sections were examined and photographed under light trinocular (Leica CM40, Germany) microscopy.

Body Composition

Dry matter and crude ash levels of whole-body in guppies were determined according to AOAC (2003). Crude protein was performed by Kjeldahl method (AOAC, 2003) and crude lipid were analyzed by automated extraction method ANKOM XT-15 (Macedon, NY).

Statistical Analysis

For statistical evaluation, SPSS version 17.0 was used and collected data was given as Mean ± SD. Statistics was performed using one-way ANOVA. Determining differences among the groups was performed through Duncan's multiple range test ($P< 0.05$).

Results and Discussion

For male and female guppies, growth performance parameters, including final weight, weight gain, feed conversion ratio, specific growth rate and survival rate, are given in Table 4. G4 diet significantly ($P<0.001$) increased the final body weight, weight gain and specific growth rate of female guppies compared to the other diets. As shown in Table 4, feeding with the G4 diet significantly ($P<0.05$) improved the FCR of female guppies compared to the G1 diet. The survival rate of female guppies fed the G4 diet was significantly ($P<0.05$) higher than the C, G1 and G2 except for the G3 diet. Feeding with the G3 and G4 diets resulted in higher growth parameters ($P<0.001$) than those of male guppies fed the C, G1 and G2 diets. FCR of male guppies was significantly ($P<0.001$) improved with the G3 and G4 diets compared to that of male guppies fed the C and G1 diets. In addition, the G3 and G4 diets significantly ($P<0.05$) improved the survival rate of male guppies compared to the C and G1 diets, except for the G2 diet,

The bacterial diversity of intestinal digesta samples of the experimental groups is presented in the phylum level in Figure 1. Fusobacteria was the most abundant phylum in C, G1, G2 and G3 groups at the rate of 77, 55, 72 and 37 %, respectively, while Proteobacteria were the second most abundant phylum among these groups as 22, 43, 26 and 31 %, respectively. However, Proteobacteria showed the most intensity in the G4 group, with a rate of 88%. Bacteroidota was found as the second most abundant phylum in the G4 group (6%).

The taxonomic distribution of the bacterial diversity of intestinal digesta samples of the experimental groups at phylum, class, order, family and genus level is detailed in Figures 2-6. In C group, *Cetobacterium* (77%), *Aeromonas* (10%), *Shewanella* (5%), *Pseudomonas* (1%); in G1 group, *Cetobacterium* (55%), *Aeromonas* (26%), *Shewanella* (6%); In G2 group, *Cetobacterium* (72%), *Aeromonas* (12%), *Shewanella* (6%), *Flavobacterium* (1%); In G3 group, *Cetobacterium* (37%), *Nocardia* (19%), *Pseudomonas* (4%), *Shewanella* (5%), *Aeromonas* (2%), *Allorhizobium-Neorhizobium-Pararhizobium-Rhizobium* (2%), *Kaistia* (2%), *Rhodococcus* (2%), *Neochlamydia* (2%), *Lysinimonas* (1%), *Mycobacterium* (1%), *Flavobacterium* (1%), *Fimbriiglobus* (1%); In G4 group, *Aeromonas* (20%), *Shewanella* (12%), *Allorhizobium-Neorhizobium-Pararhizobium-Rhizobium* (12%), *Comanonas* (11%), *Flavobacterium* (5%), *Bosea* (3%), *Shinella* (2%), *Kaistia* (1%), *Cetobacterium* (1%) were abundant at genus level..

Table 4. The effects yellow mealworm (*Tenebrio molitor*) larvae meal on growth performance of female and male guppies

		C	G1	G2	G3	G4	*p value*
Initial body weight (g)	Female	0.15±0.01	0.15±0.01	0.14±0.01	0.15±0.01	0.15±0.01	0.087
	Male	0.15±0.01	0.15±0.01	0.15±0.01	0.15±0.01	0.15±0.01	0.959
Final body weight (g)	Female	1.25±0.09^{c}	1.21±0.11^{cd}	1.18±0.10^{d}	1.54±0.08^{b}	1.66±0.09^{a}	0.000
	Male	0.49±0.05^{b}	0.51±0.07^{b}	0.41±0.04^{c}	0.64±0.03^{a}	0.64±0.04^{a}	0.000
Body weight gain (g)	Female	1.10±0.07^{c}	1.06±0.05^{c}	1.04±0.03^{c}	1.39±0.04^{b}	1.52±0.03^{a}	0.000
	Male	0.34±0.03^{b}	0.37±0.03^{b}	0.26±0.03^{c}	0.49±0.02^{a}	0.49±0.03^{a}	0.000
SGR (%)	Female	2.53±0.08^{c}	2.48±0.08^{c}	2.52±0.05^{c}	2.77±0.05^{b}	2.88±0.02^{a}	0.000
	Male	1.42±0.07^{b}	1.48±0.07^{b}	1.21±0.09^{c}	1.75±0.04^{a}	1.75±0.07^{a}	0.000
Survival rate (%)	Female	92.19±3.13^{b}	92.19±3.13^{b}	90.63±3.61^{b}	95.31±3.13^{ab}	98.44±3.13^{a}	0.026
	Male	89.06±3.13^{b}	89.06±3.13^{b}	92.19±3.13^{ab}	95.31±3.13^{a}	96.88±3.61^{a}	0.010
FCR	Female	1.65±0.02^{ab}	1.67±0.05^{a}	1.65±0.03^{ab}	1.65±0.02^{ab}	1.61±0.02^{b}	0.012
	Male	1.87±0.04^{a}	1.78±0.13^{ab}	1.69±0.06^{bc}	1.56±0.03^{d}	1.61±0.04^{cd}	0.000

Values are mean ± SD. Means in the same raw text with different superscripts are significantly different

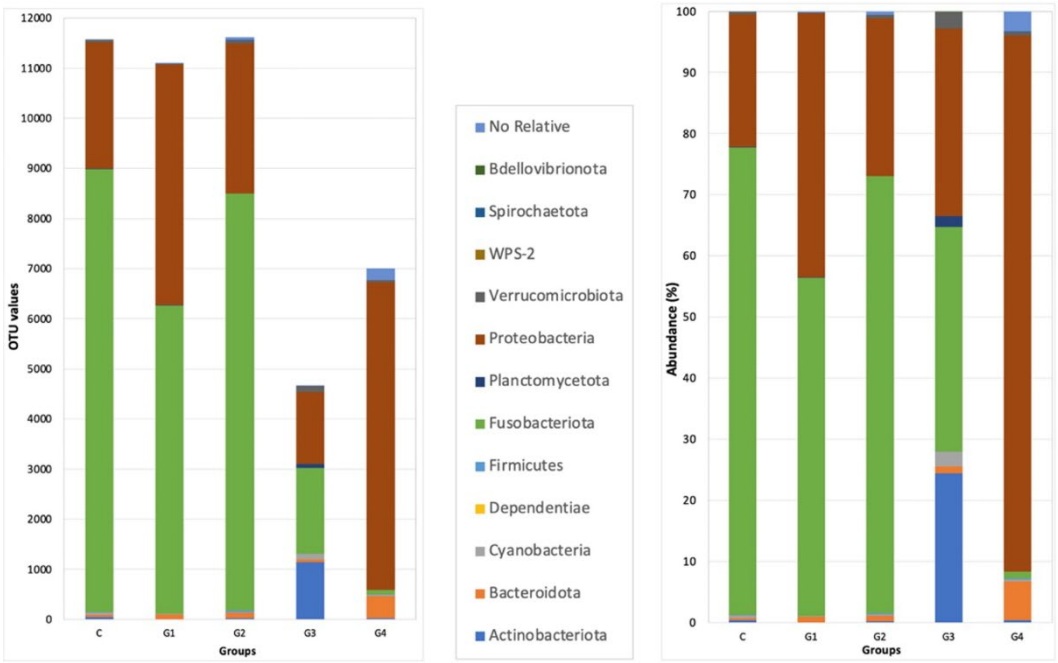

Figure 1. Relative abundance (%) and OTU values of the most prevalent bacteria among the groups at the phylum taxonomic level

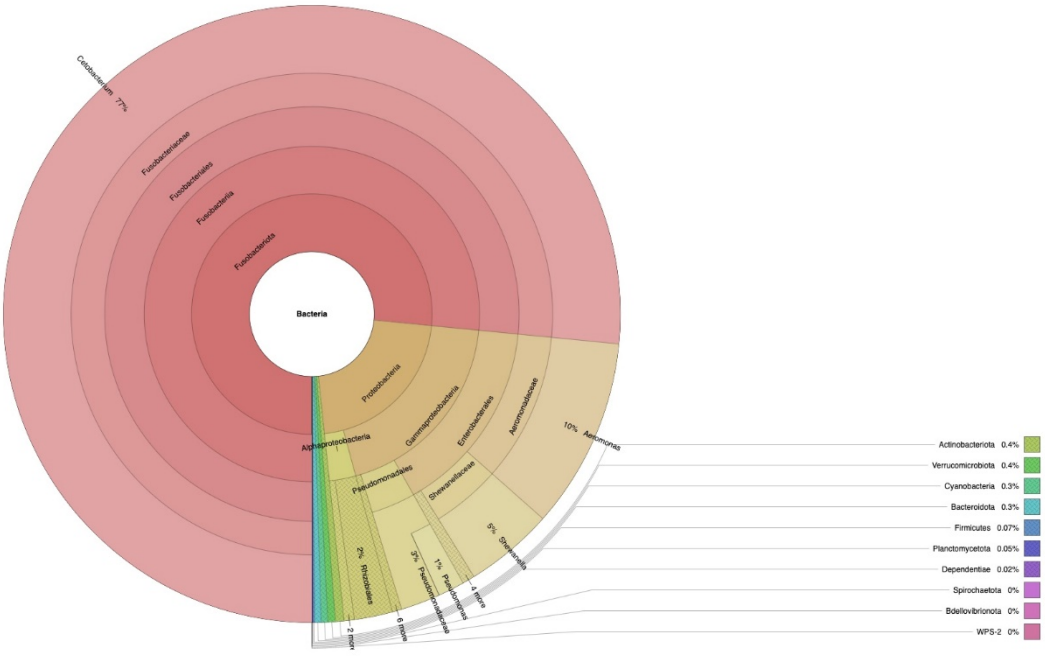

Figure 2. Krona graph of C group showing microbial population in intestinal digesta samples of guppies

Histopathological analysis of intestinal and liver tissue were compared to distinguish the effect of different feed additives in guppy fish (Figure 7). Irregular-shaped hepatocytes were seen in histological sections of the liver tissue. In general, however, tissue with a typical cord-like arrangement was identified, surrounded by hepatocytes, sinusoids, and connective tissues. In addition, lipid accumulation was found in hepatocytes, and the presence of lipoid vacuoles (as glycogen stored) in the liver was compatible with using the formulated diet. The numerous lipid vacuoles observed in hepatocytes in liver tissues of guppy showed regular and moderate infiltrations. The hepatic parenchyma was detected as sponge-like morphology, polyhedral type hepatocytes, and lipid droplets for all groups.

It is the appearance of intestinal folds, and in the histopathological examination of the intestine, it was noted that the first inflammatory reactions such as ciliary epithelium and well-distributed goblet structure and lamina propria and lamina epithelial hyperplasia were not observed. Furthermore, no remarkable difference was determined in goblet cell densities. It is seen that the use of these feed additives in guppy culture exhibited normal histomorphology in the liver and small intestine tissues.

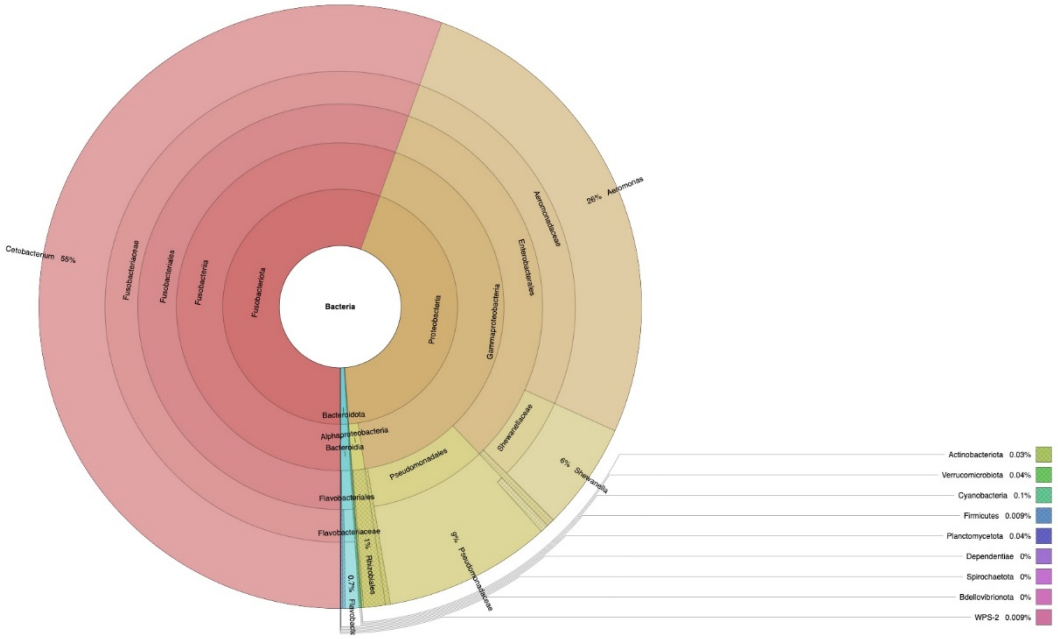

Figure 3. Krona graph of G1 group showing microbial population in intestinal digesta samples of guppies

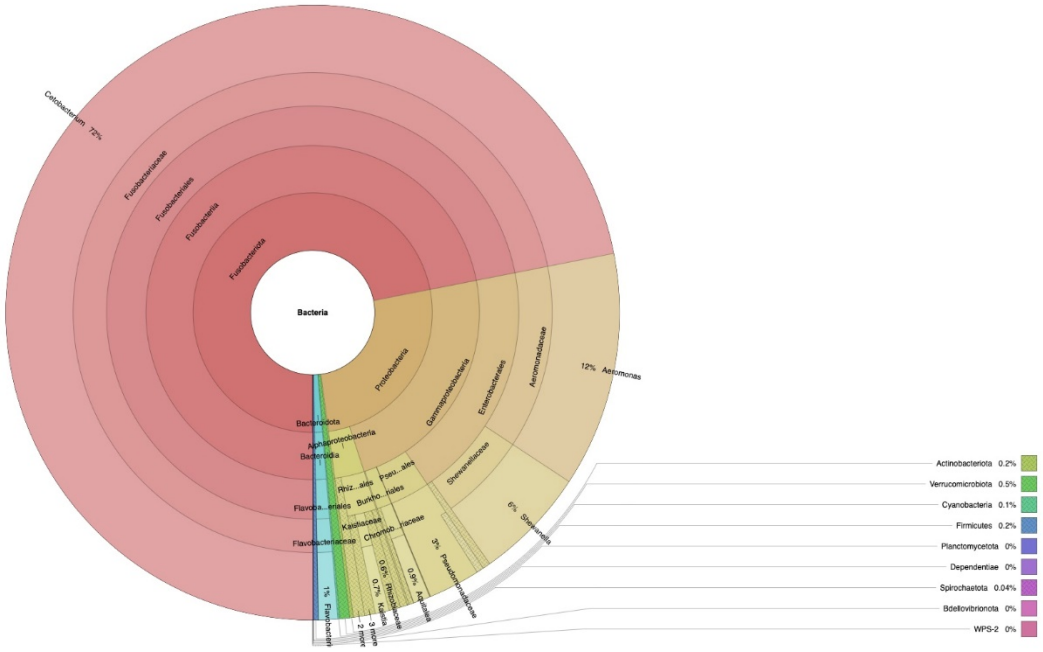

Figure 4. Krona graph of G2 group showing microbial population in intestinal digesta samples of guppies

The effects yellow mealworm (*T. molitor*) larvae meal on histomorphometric parameters of the intestine of guppies are summarized in Table 5. G4 diet had significantly ($P<0.05$) the highest villus height of the small intestine of guppies. Small intestinal villus width of guppies had the highest value in fish fed with G1 and G3 rations ($P<0.01$). Moreover, feeding with the G3 and G4 diet significantly increased the surface absorption area of the small intestine of guppies compared to feeding with other diets ($P<0.05$). Feeding with G2, G3 and G4 diets significantly reduced the crypt depth of the small intestine of guppies compared to feeding with C and G1 diets ($P<0.05$). No significant differences were observed among the groups regarding moisture, protein, lipids and ash contents of the whole body in guppies (Table 6).

Among the alternative ingredients for aquafeed, TM is one of the promising candidates in the aquaculture industry (Tran et al., 2022). The utilization of TM for partial/complete replacement of protein sources in aquafeed has been studied in detail for most cultured fish species, including yellow catfish (*Pelteobagrus fulvidraco*) (Su et al., 2017), Nile tilapia (*Oreochromis niloticus*) (Sánchez-Muros et al., 2016), rainbow trout (*Oncorhynchus mykiss*) (Chemello et al., 2020; Jeong et al., 2020), European sea bass (*Dicentrarchus labrax*) (Henry et al., 2018; Mastoraki et al., 2020; Basto et al., 2020), gilthead sea bream (*Sparus aurata*) (Piccolo et al., 2017), Atlantic salmon (*Salmo salar*) (Biancarosa et al., 2019), and red seabream (*Pargus major*) (Ido et al., 2019).

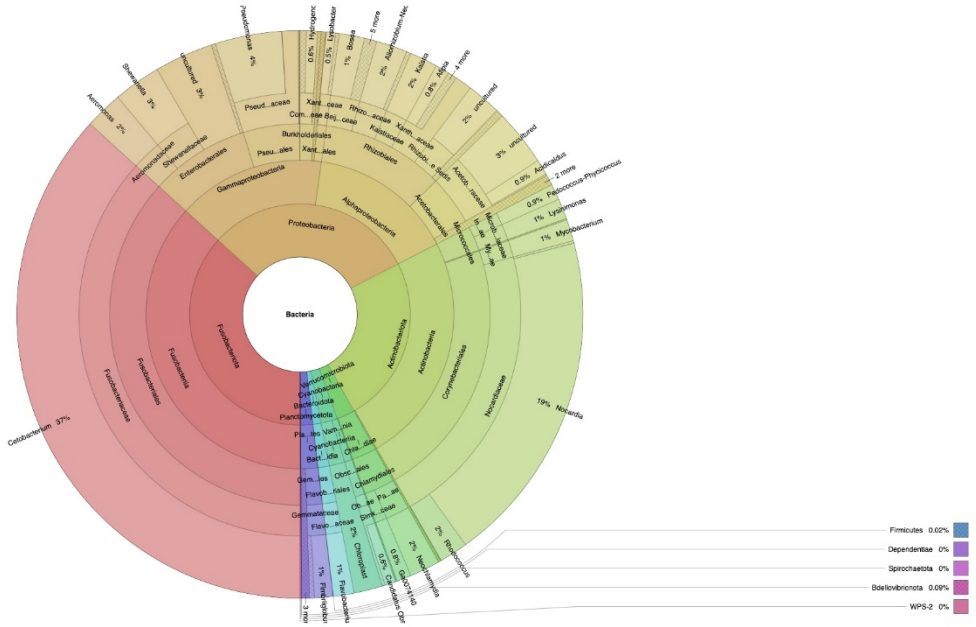

Figure 5. Krona graph of G3 group showing microbial population in intestinal digesta samples of guppies

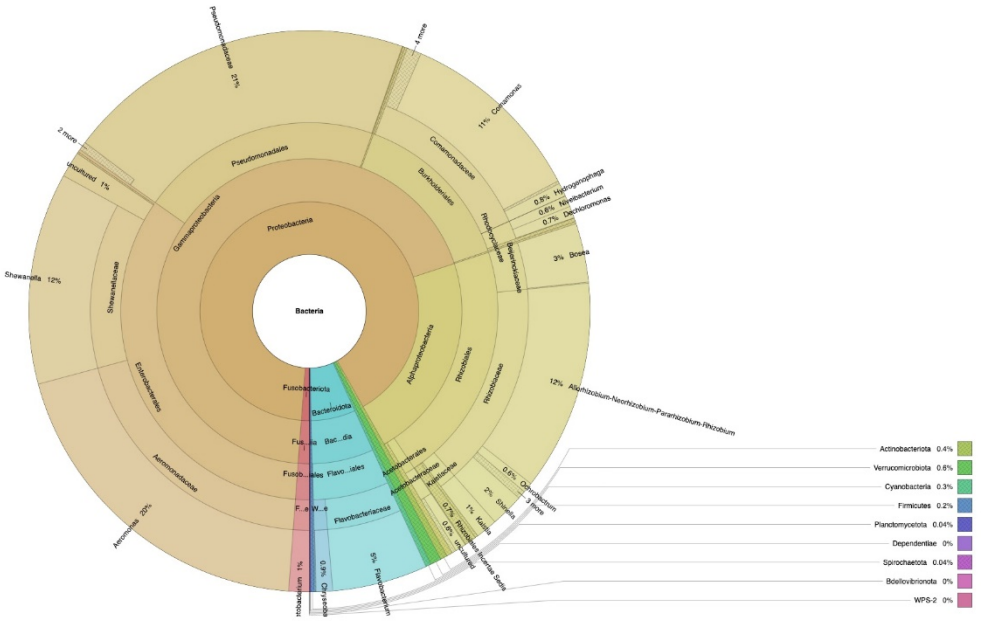

Figure 6. Krona graph of G4 group showing microbial population in intestinal digesta samples of guppies

Table 5. The effects yellow mealworm (*T. molitor*) larvae meal on histomorphometric parameters of intestine of guppies

Histomorphometric parameters	C	G1	G2	G3	G4	p value
Villus height, µm	138.80±26.90^{d}	151.20±41.74^{c}	159.40±66.06^{c}	184.40±31.50^{b}	194.40±34.07^{a}	0.024
Villus width, µm	36.60±11.24^{c}	60.80±11.63^{a}	53.00±1.83^{b}	64.00±10.25^{a}	57.80±5.68^{b}	0.001
Villus surface area, µm^2	5.13±2.07^{c}	9.47±3.80^{b}	10.17±4.40^{b}	11.32±3.04^{a}	11.09±1.16^{a}	0.033
Crypt depth, µm	4.80±0.84^{a}	4.60±0.65^{a}	3.70±1.04^{b}	3.60±0.42^{b}	3.20±1.04^{b}	0.028

Values are mean ± SD. Means in the same raw text with different superscripts are significantly

Table 6. Nutrient composition of whole-body on a wet weight basis (%)

	C	G1	G2	G3	G4	p value
Moisture	77.10±0.30	77.53±0.23	77.00±0.36	77.07±0.29	76.73±0.2	0.066
Lipids	3.30±0.36	3.60±0.17	3.37±0.15	3.37±0.51	3.27±0.32	0.761
Protein	13.73±0.21	13.87±0.38	14.03±0.42	14.03±0.15	14.10±0.00	0.508
Ash	3.63±0.15	3.47±0.12	3.60±0.10	3.57±0.21	3.50±0.17	0.673

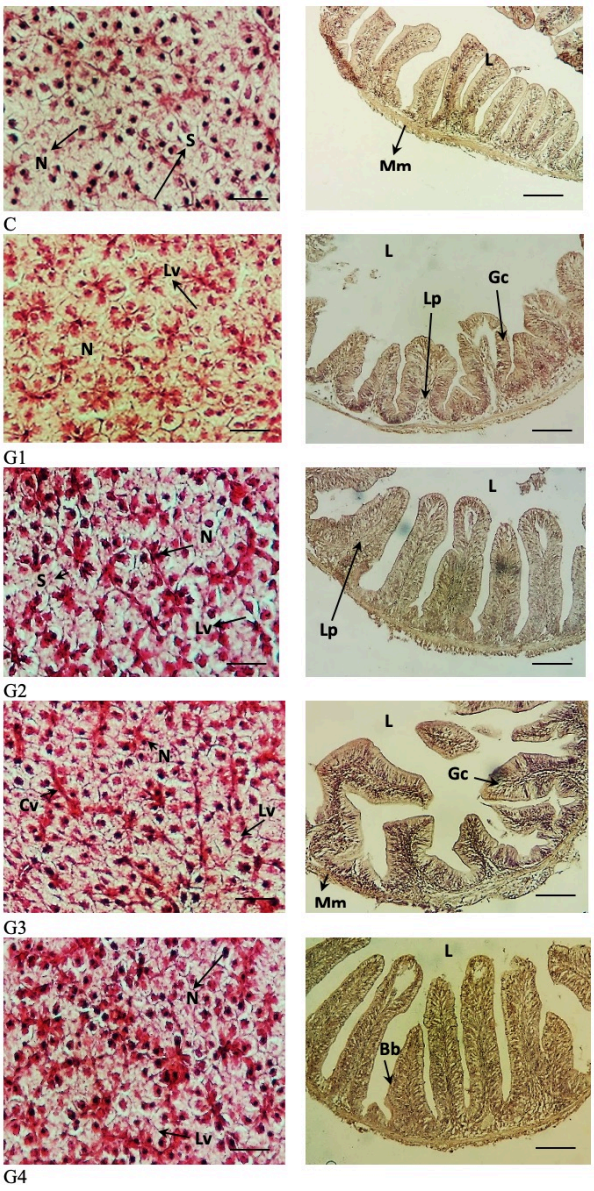

Figure 7. The liver (left column) and small intestine (right column) histology sections of guppies fed with the non-fermented and fermented Tenebrio molitor base meals.
N: hepatocyte nucleus, Lv: lipoid vacuoles, S: sinusoids, and C: capillary vessels, Gc: goblet cell, Lp: lamina propria, Bb: brush border, L: lumen, Mm: muscularis mucosa (H&E, x400, bar: 50 µm).

Although TM is not only considered as a substitution material but also as a functional feed additive, there is no information on its use as a feed additive in fish culture. This study indicates the first attempt at the possibility of using solid-state fermented DTML as a functional antibacterial feed additive in guppies. In a study conducted by Wang et. al. (2020), the addition of 0.4% solid-state fermented wheat bran polysaccharides to the diet increased the growth performance of common carp compared to the control group. Also, it was reported that the inclusion of 0.5% solid-state fermentation product (Synergen™) to the diet could significantly increase growth performance and feed efficiency of rainbow trout. In the present study, the inclusion of the solid-state fermented DTML with *L. plantarum*, particularly *L. plantarum* plus *L. brevis* as a feed additive, resulted in better growth indices of *P. reticulata* after 84 days. The better growth performance values obtained in the G4 groups can be attributed to the feed additive, which gained functional quality after fermentation with *L. plantarum* and *L. brevis*, by improving the intestinal microbiota and increasing nutrient absorption. *Lactobacillus* spp. and *Saccharomyces* spp. called probiotics are frequently used in animal breeding as a fermentation and feed additive (Wang et al., 2018; Wang & Jin, 2019; Zhang et al., 2021).

Furthermore, combinations of probiotics prove to be more effective in aquaculture compared to using individual probiotic strains (Lin et al., 2017). In parallel with our results, in a study conducted by Zhang et al. (2021), it was concluded that fermented feed with probiotics mixture increased growth indices in *Penaeus vannamei*. According to another previous study by Lin et al. (2017), it was stated that the synergistic effect of the probiotic mixture as a feed additive improved growth performance for *Lates calcarifer*.

The gut microbiome plays a crucial role in improving the digestion of nutrients and promoting healthy fish growth (Ganguly & Prasad, 2012). In some previous studies, it was stated that the inclusion of TM in the diet did not affect the gut microbiota (Mikołajczak et al., 2020; Terova et al., 2021; Jeong et al., 2021). In contrast, in others, it was claimed that the gut microbiota changed significantly (Antonopoulou et al., 2019; Józefiak et al., 2019). However, it was stated that fermented feed with mixed probiotics could improve species richness and evenness of shrimp microbiota (Zang et al., 2021). In our study, while unfermented DTML did not vary the gut microbiota, fermented DTML with *L. plantarum* and *L. brevis* feed additive increased gut microbiota diversity in the guppies. This critical difference among the groups may be due to the synergistic effect of the feed additive fermented with different probiotics in the intestine and the bioactive substances found in the DTML. Contrasting data from the current literature may depend on determinant parameters such as the rearing medium of TM or TML used as a feed ingredient and the quantity of protein and lipid in its body. These differences can also be attributed to the fish species, inclusion levels and nutrient requirements.

Fusobacteria is often identified as the most common phylum in freshwater fish (Roeselers et al., 2011; Ghanbari et al., 2015; Parata et al., 2020). In agreement with the previous data, Fusobacteria were a major constituent of the guppies microbiome in the C, G1, G2 and G3 groups. However, the most prevalent bacteria in the samples of guppies fed fermented with *L. plantarum* plus *L. brevis* feed additive were Proteobacteria phylum. In different studies, it was indicated that the Proteobacteria may differ depending on diet formulation (Ingerslev et al., 2014; Gajardo et al., 2016). This approves that the inclusion of the fermented DTML with two probiotics changed the dominant phylum in the G4 group when compared to the other groups. Within this phylum, bacteria such as *Aeromonas*, *Pseudomonas* and *Shewanella* were increased in the G4 group. Although *Aeromonas* is primarily associated with disease, it is found in the GI tract of healthy finfish (Abdelhamed et al., 2019). There is general information regarding using *Aeromonas* as a probiotic in fish culture (Chi et al., 2014; Wu et al., 2015; Hao et al., 2017). Various studies have also shown the probiotic potential of Pseudomonas (Giri et al., 2011; 2015; 2016). The genus *Shewanella* is used commonly as a probiotic in

finfish culture (Chabrillón et al., 2005a; 2005b). In the present study, it can be stated that fermented probiotic mixture stimulated gut microbiota with beneficial probiotic bacteria.

With the morphometric measurement of intestinal villi height and width, the mechanism of absorption and digestion in the fish intestine can be predicted (Rašković et al., 2011). In our study, the measured intestinal villus height, width, and surface area increased in all experimental groups compared to the control group, reaching the highest value in fish fed DTMLM fermented with *L. plantarum* plus *L. brevis*. The improved feed utilization in fish fed fermented feed additives could be attributed to the increasing values of the intestinal villi, thus improving metabolism and nutrient absorption. Consistent with our study data, villus length of the intestinal sections was enhanced in fish fed yeast fermented PBM in common carp (Dawood et al., 2020b) and in fish fed yeast fermented date palm seed meal in Nile tilapia (Dawood et al., 2020a).

In our study, DTML feed additive did not change the nutrient composition of whole body in guppies. Similar results were obtained in studies in which DTML was included in the diet at different levels (Sankian et al., 2018; Rema et al., 2019; Tran et al., 2022).

In conclusion, the findings of this study compellingly demonstrate that the inclusion of 2 g/kg *L. plantarum* and 2 g/kg *L. brevis* fermented DTML significantly enhances the growth performance of guppies. This improvement is attributed to the positive modulation of gut microbiota and the enhancement of gut histomorphology, offering substantial implications for scientists in the field of aquaculture and aquarium fish industry. However, the inclusion of fermented DTML as a feed additive needs to be tested in further research to identify the mechanisms for cultured fish species.

Declarations

Acknowledgement

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Declaration of Competing Interest

The authors declare no conflicts of interest.

Data Availability

Data will be made available on request.

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Improving Energy Efficiency and Environmental Mitigation Through Irrigation Management in Irrigated-Wheat Production

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ABSTRACT

The aim of this work was to evaluate the potential for environmental mitigation, including the reduction of total greenhouse gas (GHG) emissions from agricultural inputs, and the potential for improving the energy efficiency in winter wheat production by managing irrigation water. In this context, the data on the required production inputs and product yield were obtained from the field experiment on supplemental irrigation in wheat in Konya in the 2018-2020 period. Five different irrigation regimes were considered in the study, namely: TTS, irrigation equal to the amount of moisture reduction in the 0-90 cm soil layer during the three critical development periods of wheat; KTS-1, irrigation with 90 mm of water during the three critical development periods of wheat; KTS-2, irrigation with 70 mm of water during the three critical development periods of wheat; KTS-3, irrigation with 50 mm of water during the three critical development periods of wheat, and Y, non -irrigated (rainfed). According to the results obtained from the study, the highest grain yield (7918 kg ha^{-1}) and energy output (285857 MJ ha^{-1}) were obtained in the TTS application, while the best energy productivity (0,935 kg MJ^{-1}) with energy efficiency ratio (12,46) and the lowest environmental pollution (2272 kgCO2 eq ha^{-1}) were achieved under the KTS-3 regime. The analysis of energy efficiency and environmental pollution in this research led to very important findings. In regions like Konya, where agricultural land is abundant and water resources are limited, it has been observed that instead of full irrigation (TTS) where high yield per unit area (1 ha) is obtained, the same amount of product can be produced from 1,04 ha under KTS-2 and 1,09 ha under KTS-3 regime. In this way, irrigation water savings of 32,4% to 49% can be achieved without a decrease in product quantity, while greenhouse gas emissions can be reduced by 10,3% to 15,6%.

Türk Tarım – Gıda Bilim ve Teknoloji Dergisi, 13(1): 194-203, 2025

Sulamalı Buğday Üretiminde Sulama Yönetimi Yoluyla Enerji Verimliliğinin İyileştirilmesi ve Çevresel Etkinin Azaltılması

MAKALE BİLGİSİ

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ÖZ

Bu çalışmanın amacı sulamalı buğday üretiminde, üretim girdilerinden kaynaklanan toplam sera gazı (GHG) emisyonlarının azaltılması da dahil olmak üzere, sulama yönetimi yoluyla buğday üretiminde enerji verimliliğini artırma ve çevresel etkiyi azaltma potansiyelini değerlendirmektir. Bu kapsamda gerekli olan üretim girdileri ve ürün verimine ilişkin veriler, 2018-2020 döneminde, Konya'da buğdayda tamamlayıcı sulama üzerine yürütülen tarla denemesinden elde edilmiştir. Bu bağlamda beş farklı sulama rejimi dikkate alınmış olup, bunlar: TTS, buğdayın üç kritik gelişme döneminde, 0-90 cm toprak katmanında eksilen nem miktarı kadar sulama; KTS-1, buğdayın üç kritik gelişme döneminde 90'ar mm su ile sulama; KTS-2, buğdayın üç kritik gelişme döneminde 70'er mm su ile sulama; KTS-3, buğdayın üç kritik gelişme döneminde 50'şer mm su ile sulama ve Y, yağışa dayalı konudur. Çalışmadan elde edilen sonuçlara göre, en yüksek dane verimi (7918 kg ha^{-1}) ve enerji çıktısı (285857 MJ ha^{-1}) TTS uygulamasında elde edilirken, en iyi enerji üretkenliği (0,935 kg MJ^{-1}) ile enerji verimliliği oranı (12,46) ve en düşük çevre kirliliği (2272 kgCO_2 eşd ha^{-1}) KTS-3 rejimi altında gerçekleşmiştir. Çalışma kapsamındaki enerji verimliliği ve çevresel kirlilik analizi önemli bulgulara yol açmıştır. Konya gibi tarım arazisi çok, su kaynakları kısıtlı olan bölgelerde, birim alandan (1 ha) yüksek verimin elde edildiği tam sulama (TTS) yerine, aynı ürün miktarının KTS-2 altında 1,04 ha ve KTS-3 rejimi altında ise 1,09 ha'dan üretilebileceği görülmüştür. Bu yolla, ürün miktarında bir azalış olmadan, sulama suyunda %32,4 ile %49 arasında bir tasarruf sağlanırken, sera gazı emisyonu ise %10,3 ile %15,6 arasında azaltılabilecektir.

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Giriş

Buğday dünyadaki önemli tahıllardan biridir ve dünyada düşük gelirli haneler arasında önemli bir yere sahiptir (Taki ve ark., 2016). Buğday, insan ve hayvan beslenmesinde kullanılan önemli bir ürün olup, dünyada en çok ekilen bitkilerden biridir. USDA (2021) verilerine göre 2019-2020 üretim sezonunda dünya genelinde 215,6 milyon ha alanda buğday ekimi yapılmış ve 762,2 milyon ton üretim gerçekleşmiştir. Aynı dönemde dünya buğday ekim alanının %55,3'ünü Hindistan, Rusya, AB, Çin ve ABD'den oluşan 5 ülke oluştururken, bu ülkeler dünya buğday üretiminin de yaklaşık %65,9'unu gerçekleştirmişlerdir. Türkiye ise dünya buğday üretiminde 10'ununcu büyük üretici ülke durumundadır. Türkiye'de 2022-2023 yetiştirme yılında 6,83 milyon ha alanda buğday tarımı yapılmış ve 22 milyon ton üretim gerçekleştirilmiştir (TÜİK, 2024a).

Türkiye'de 2023 yılı verilerine göre buğday üretiminin ekim alan olarak %8,71'i ve üretim miktarı olarak yaklaşık %10'u tek başına Konya ilinde gerçekleşmektedir (Anonim, 2024). Buğday, Konya bölgesinde hem suluda ve hem de yağışa dayalı olarak tarımı yapılmaktadır. Konya bölgesinde kışlık buğday için tahmin edilen mevsimlik su tüketimi 500 -550 mm arasında değişirken (Anonim, 2017), yıllık yağış miktarı uzun dönem (1985-2020) ortalaması olarak 326 mm kadardır (MBM, 2021). Bölgedeki düşük yağış ve yağışların yıl içindeki dağılımının düzensiz olması yüksek verim için sulamayı zorunlu kılmaktadır. DSİ (2021) verilerine göre, Konya 2,94 milyar m^3'ü yerüstü, 1,5 milyar m^3'ü yeraltı olmak üzere toplam 4,45 milyar m^3 su potansiyeline sahiptir. Toplam su potansiyelin kullanılabilir miktarı ise 2.5 milyar m^3 kadardır. Bölgede yeraltı suları (YAS) temel sulama suyu kaynağını oluşturmaktadır. Konya'nın toplam 1,88 milyon ha tarım alanı (Anonim, 2024) ve mevcut bitki deseni dikkate alındığında, ilin su kaynakları varlığının çok kısıtlı olduğu görülmektedir. Konya bölgesinde yaklaşık 609 bin ha tarım alanı sulamaya açılmış (Anonim, 2024) olup, bunun 165 000 ha'ı yerüstü su kaynakları (DSİ, 2023) ile geri kalan 444 bin hektarlık bölümü ise yeraltı su kaynakları ile sulanmaktadır. DSİ (2020) verilerine göre Konya bölgesinde ruhsatlı 22006 ve ruhsatsız 41071 olmak üzere toplam 63077 adet bireysel YAS sulama kuyusu ile 3256 civarında sulama kooperatifi kuyusu bulunmaktadır. Görüldüğü üzere, il düzeyindeki sulama alanının yaklaşık %73'ünün sulama suyu ihtiyacı YAS kaynaklarından elektrikle işletilen kuyularla karşılanmaktadır. Bölgede sulama kuyuları önemli bir enerji tüketicisidir. Özellikle plansız şekilde açılan ruhsatsız kuyularla emniyetli rezervin dışında aşırı çekim yapıldığı için havzada YAS seviyesi her yıl daha aşağıya düşmektedir. Bunun sonucu olarak tarımsal sulamada elektrik tüketimi artmakta ve dolayısıyla daha çok sera gazı (SG) emisyonu ortaya çıkmaktadır. Kısacası Konya Ovasında sulama önemli bir enerji kullanıcısı ve önemli bir sera gazı emisyon unsurudur.

Tarımsal alanda enerji, üretkenliği artırma, gıda güvenliğini geliştirme ve kırsal ekonomik kalkınmaya katkıda bulunma gibi çeşitli nedenlerle kullanılan bir girdidir (FAO, 2000). Enerji, kalkınmanın önemli bir itici gücü olup, tarım sektöründe özellikle etkilidir. Çünkü tarım hem bir enerji tüketicisi hem de üreticisidir. Bitkiler, biyokütle üretmek için güneş enerjisini kullanırken, ana karbon kaynağı olarak atmosferik karbondioksiti (CO_2) kullanmaktadır. Tarım, güneş enerjisini biyokütleye dönüştüren ürünler yetiştirerek enerji üretir ve bu da insanlara ve hayvanlara enerji sağlar. Ancak tarım; tohum, motorin, elektrik, gübre, bitki koruma kimyasalları, makine ve insan emeği gibi büyük miktarda enerji girdisi kullanır.

Bazı bitkilerin enerji girdi–çıktı analizleri üzerine çalışan araştırıcılara göre (Mrini ve ark., 2002; Singh ve ark., 2003; Topak ve ark., 2005; Karimi ve ark., 2008; Davoodi ve Housyar, 2009; Mantineo ve ark., 2009; Topak ve ark., 2010; Yavuz ve ark., 2016; Ceran, 2020; Halkacı, 2022) toplam enerji girdisinin çok büyük bir bölümü sulama işleminden kaynaklanmaktadır. Enerji tüketiminin yanı sıra sera gazı emisyonu ve küresel ısınma potansiyeli konuları da tarımsal üretim sistemlerinde kritik öneme sahip hale gelmiştir (Khoshnevisan ve ark., 2013). Çünkü bitkisel üretimde, üretim faaliyetleri sonucu ortaya çıkan sera gazları, doğal sera etkisini arttırmaktadır. Bununla birlikte, bitkiler fotosentez süreci yoluyla havadaki CO_2'yi kullanarak azaltırken, kendisinin üretimi de bir sera gazı emisyonu kaynağıdır.

Bitkisel üretimin neden olduğu çevresel etkiler üzerine yapılan bazı araştırmalarda, tarımsal kurak bölgelerde sulama işleminin en çok enerji tüketen faaliyet olduğu ve dolayısıyla sulama işleminin önemli seviyede sera gazı emisyonuna neden olduğu bildirilmiştir (Wang ve ark., 2016; Yousefi ve ark., 2014; Mohammadi ve ark., 2013). Bu bağlamda, bazı araştırıcılar sulama kaynaklı sera gazı emisyonu payını; şekerpancarı için %33-53 (Topak ve Kalender, 2020) ve %46 (Halkacı, 2022), yağlık ayçiçeğinde %35-63 (Topak ve Ceran, 2021), mısır için %47 (Nisar ve ark., 2021) ve kışlık buğday için ise %46 (Gao ve ark., 2022), %45-55 (He ve ark., 2017) %52 (Rafiee ve ark., 2022) ve %66 (Nisar ve ark., 2021) olarak belirlemişlerdir.

Sera gazı envanteri sonuçlarına göre, Türkiye'de 2022 yılında toplam 558,3 milyon ton CO_2 eşd sera gazı emisyonu gerçekleşmiş olup, bu miktarın %12,8'ini tarım sektöründen kaynaklanan sera gazı emisyonları oluşturmuştur (TÜİK, 2024b). Konya kapalı havzasında 2020 yılı sulaması için %93,3'ü yeraltı su kaynaklarından yapılan sulamada olmak üzere toplam 1,7 milyon ton CO_2 eşd sera gazı emisyonu gerçekleştiği belirlenmiştir (Kalender, 2023). Dünya genelinde kurak ve yarı kurak bölgelerde, sulu tarım yeraltı ve yerüstü su kaynaklarından sulama suyu temini büyük ölçüde enerji kaynaklarına dayanmaktadır (He ve ark., 2017). Yeraltı suyunu kullanarak tarımsal sulama dünya çapında giderek yaygınlaşmaktadır (McGill ve ark., 2018). Günümüzde, tarımsal sulama için tüketilen enerji, sera gazı emisyonları da dahil olmak üzere önemli çevresel sonuçları ortaya çıkarmaktadır (Khan ve ark., 2014; Pradeleix ve ark., 2015).

İklim değişikliği ile mücadele, uyum sağlama ve azaltım tedbirlerini zorunlu kılmaktadır (Black ve ark., 2011). Azaltım, insan kaynaklı net sera gazı emisyonlarını azaltmak için yapılan bir müdahaledir (Glantz ve ark., 2009). Bitki ile kaplı alanların artırılması iklim değişikliği ile mücadelede azaltım başlığı altında

değerlendirilmektedir (Spittlehouse ve Stewart, 2003). Bu da göstermektedir ki tarımsal üretim hem doğrudan sera gazı emisyonu azaltımına katkı sağlamakta ve hem de gıda güvenliğimizi garanti altına almaktadır. Ancak bitkisel üretim faaliyetleri neticesi açığa çıkan ve iklim değişikliğine katkı sunan sera gazlarının minimal seviyede olması büyük önem arz etmektedir. Bu çalışmada kısıtlı su kaynaklarına sahip Konya bölgesinde, buğday tarımında farklı tamamlayıcı sulama rejimleri uygulamasının buğday üretiminin enerji verimliliğine ve çevresel kirliliğe etkisi değerlendirilmiştir.

Materyal ve Metot

Bu makalede, sulamalı kışlık buğday üretim girdileri ve çıktıları ile bunlara ilişkin enerji eşdeğeri ve sera gazı emisyon faktörü değerleri kullanılmıştır. Kışlık buğdayın üretim verileri, Konya'da Toprak Su ve Çölleşeme ile Mücadele Araştırma Enstitüsü'nde 2018/2019 ve 2019/2020 üretim yıllarında yürütülen tarla denemesinden toplanmıştır. Üretim girdileri ile çıktılarına ilişkin enerji eşdeğeri ve sera gazı emisyon faktörü değerleri literatürden derlenmiştir. Tarla denemesinin yürütüldüğü 2018, 2019 ve 2020 yıllarında yıllık yağış miktarı sırasıyla 306, 330 ve 217 mm olarak gerçekleşmiştir (TSÇMAE, 2020). Bu yılların aylık yağış verileri dikkate alındığında, 2018-2019 ve 2019-2020 üretim yıllarında buğdayın yetişme döneminde (10 Ekim -1 Temmuz) düşen yağış miktarları sırasıyla 260 ve 276 mm olmuştur. Her iki üretim yılında da buğday üzerine düşen yağış miktarı, bölgenin uzun yıllar yağış ortalamasının (292 mm) altında gerçekleşmiştir. Buğday bitkisinin bölgede suya en çok ihtiyaç duyduğu dönemde (Nisan + Mayıs + Haziran); buğday üzerine düşen yağış miktarı 2019 yılında 70 mm, 2020 yılında ise 50 mm olarak gerçekleşmiştir (TSÇMAE, 2020).

Denemenin yürütüldüğü tarla parseli kulaklı pullukla sürülmüş, kazayağı, kombi kürüm ve merdane ile toprak işlenerek ekime hazır hale getirilmiştir. Tohum ekimi, kombine hububat ekim mibzeri ile 2018'de 19 Ekim, hasat 12 Temmuz ve 2019 yılında ise 24 Ekim, hasat ise 19 Temmuz tarihlerinde yapılmıştır. Hasat işlemi parsel biçerdöveri ile gerçekleştirilmiştir. Ekimde dekara 20 kg tohumluk kullanılmıştır. Deneme alanı bütün halinde ekilmiş ve çıkış sonrası parsel bitkilerce örtüldüğü dönemde deneme parsellerine ayrılmıştır.

Tarla denemesinde, her araştırma konusuna saf madde olarak, 160 kg ha^{-1} azot ve 100 kg ha^{-1} fosfor hesabıyla gübreleme yapılmıştır. Fosforun tamamı Diamonyum fosfat (%18-46) gübresi (220 kg ha^{-1}) ile ekimde tabana uygulanmıştır. Azotun bir kısmı ekimle birlikte tabana, kalan kısmı ise üst gübresi olarak buğdayın; kardeşlenme döneminde üre gübresi (%46) (150 kg ha^{-1}), sapa kalkma ve başaklanma dönemlerinde ise sulamalarla birlikte Amonyumsülfat (%21) gübresi (250 kg ha^{-1}) ile uygulanmıştır. Ayrıca, yağışa bağlı konuda (Y) ekimle birlikte fosforun tamamı ve azotlu gübrenin bir kısmı tabana uygulanmış, yağış durumuna göre üst gübresinin tamamı üre gübresi (%46) olarak buğdayın kardeşlenme döneminde tek seferde uygulanmıştır.

Bu makalede farklı tamamlayıcı sulama rejimleri altında buğday üretiminin enerji verimliliği ile çevreye olan etkisi değerlendirilmiştir. Bu kapsamda, farklı tamamlayıcı sulama stratejileri ve yağışa dayalı (Y) üretim olmak üzere toplam beş araştırma konusunun üretim girdi ve çıktıları bu çalışma kapsamında kullanılmıştır. Tamamlayıcı sulama stratejileri, buğdayın sapa kalkma (SK), başaklanma (BŞ) ve süt olum (SO) dönemlerinde farklı seviyelerdeki sulamalardan oluşmuştur**.** Bu kapsamda, biri toprak nemine dayalı olmak üzere dört farklı tamamlayıcı sulama konusu dikkate alınmıştır. Birincisinde (TTS), sapa kalkma, başaklanma ve süt olum dönemleri başında; bitki kök bölgesi mevcut nemi belirlenmiş ve mevcut nem sulama ile tarla kapasitesine ulaştırılmıştır. İkincisinde (KTS-1), sapa kalkmada 90 mm, başaklanma 90 mm ve süt olumda 90 mm sulanmıştır. Üçüncüsünde (KTS-2), sapa kalkmada 70 mm, başaklanma 70 mm ve süt olumda 70 mm sulanmıştır. Dördüncüsünde (KTS-3), sapa kalkmada 50 mm, başaklanma 50 mm ve süt olumda 50 mm sulanmıştır. Böylece KTS-1 konusuna 270 mm, KTS-2 konusuna 210 mm ve KTS-3 konusuna ise 150 mm sulama suyu uygulanmıştır. Uygulanan tamamlayıcı sulama rejimlerine ilişkin detaylı bilgiler Çizelge 1'de ve toprak nemine dayalı olmayan tamamlayıcı sulama rejimlerinde, bitki kritik dönemlerinde, TTS uygulamasına göre gerçekleşmiş olan sulama suyu kısıntı oranları Çizelge 2'de verilmiştir.

Tarla denemesinde sulama suyu, parsel yakınındaki derin kuyudan temin edilmiş olup, TTS, KTS-1, KTS-2 ve KTS-3 sulama stratejilerinde sırasıyla 1581, 1323, 1034 ve 738 kWh elektrik tüketimi gerçekleşmiştir. Sulama rejimleri altında yapılan buğday üretiminde eşit şekilde hektar başına 135 litre dizel yakıtı kullanılmıştır. Üretimde kullanılan tarım makinelerine ilişkin bilgiler Çizelge 3'de verildiği gibidir.

Farklı sulama rejimleri altında buğday üretimine ilişkin iki yıl ortalaması olarak sulama suyu miktarları ile ürün verim değerleri Çizelge 4'de verildiği gibidir.

Çizelge 4'de görüldüğü gibi, iki yılın ortalaması olarak TTS stratejisinde 321 mm ile en yüksek ve KTS-3 rejiminde ise 150 mm ile en düşük seviyede sulama suyu uygulanmıştır. İki yıl ortalaması olarak 7918 kg ha^{-1} ile en yüksek dane verimi TTS konusunda gerçekleşmiş olup, bunu sırasıyla KTS-1 (7688 kg ha^{-1}), KTS-2 (7660 kg ha^{-1}) ve KTS-3 (7285 kg ha^{-1}) stratejileri izlemiştir. Bu verilere göre, KTS-1 ile KTS-2 rejimlerinin dane verimleri arasında bir fark yoktur. Ancak KTS-2 rejiminde 60 mm daha az sulama suyu kullanılmıştır ve dolayısıyla KTS-2 rejimi, KTS-1'in üstünüdür ve KTS-1 uygulamasını geçersiz hale getirmiştir.

Enerji Analizleri ve Verimlilik Göstergeleri

Farklı tamamlayıcı sulama rejimleri altında buğday üretiminin enerji verimliliğini karşılaştırmak için enerji girdi-çıktı analizi yapılmıştır. Kışlık buğdayın üretim girdileri; dizel yakıtı, elektrik, tarım makineleri ve gübre girdilerinden oluşmuştur. Buğdayın ürün çıktısı ise dane ve samanıdır. Buğday üretiminin girdi ve çıktı değişkenleri, literatürden derlenen enerji katsayıları kullanılarak (Çizelge 5), megajul (MJ) biriminde enerji eşdeğerine dönüştürülmüştür. Üretimde tüketilen enerji (EG) ile üretilen enerji (EÇ) miktarları her bir sulama stratejisi için ayrı ayrı hesaplanmıştır.

Buğdayın enerji girdisi (EG), enerji değerlendirmesinin önemli bir göstergesi olup, sulama işlemi ve buğdayın tüm üretim süreci için ne kadar enerji tüketildiğini gösterir.

Enerji çıktısı (EÇ), ürün veriminin (tane ve saman) (kg ha^{-1}) enerji eşdeğeriyle çarpılmasıyla hesaplanmıştır. Bir üretim sisteminin enerji verimliliğini değerlendirmek için kullanılan göstergeler vardır (Yuan ve Peng, 2017; Taki ve ark., 2018a). Bu çalışmada, net enerji verimi (NEV), enerji verimlilik oranı (EVO), enerji üretkenliği (EÜ) ve sulamanın enerji üretkenliği (SEÜ) gibi dört önemli gösterge kullanılmıştır.

Her bir makinenin enerji tüketimini ve buğday üretimindeki payını hesaplamak için, makinelerin etkin kullanım ömrü ve makina ağırlığı önemli faktörlerdir. Her makinenin ve ekipmanın payını ve enerjisini hesaplamak için aşağıdaki eşitlik kullanılmıştır (Ramedani ve ark., 2011). Burada; ME, makine enerjisi (MJ ha^{-1}); G, makine ağırlığı (kg); E_M, traktör veya makinanın birim ağırlığı başına imalat enerjisi eşdeğeri (MJ kg^{-1}); T, traktör veya makinanın ekonomik ömrü (h) ve Th, buğday üretim sezonunda traktör ve makinelerin her birinin birim alan başına çalışma süresini (h ha^{-1}) göstermektedir.

$$ME = E_M \times G/T \times Th \quad (1)$$

Birim alan (ha) başına enerji girdisi ve enerji çıktısı ile verimlilik değerlendirme göstergeleri aşağıdaki eşitliklerde verildiği gibi hesaplanmıştır.

$$EG\ (MJ\ ha^{-1}) = E \times E_1 + D \times E_2 + G \times E_3 + ME \quad (2)$$

$$EÇ_T\ (MJ\ ha^{-1}) = DV \times EE + SV \times EE \quad (3)$$

$$EVO = EÇ_T\ (MJ\ ha^{-1}) / EG\ (MJ\ ha^{-1}) \quad (4)$$

$$EÜ\ (kg\ MJ^{-1}) = DV / EG\ (MJ\ ha^{-1}) \quad (5)$$

$$NEV\ (MJ\ ha^{-1}) = EÇ_T\ (MJ\ ha^{-1}) - EG\ (MJ\ ha^{-1}) \quad (6)$$

$$SEÜ\ (MJ\ m^{-3}) = SU - YA / TSM$$

E : Sulama için yıllık elektrik tüketimi (kWh);
E_1 : Elektriğin enerji değeri (MJ kWh^{-1});
D : Buğday üretiminde tüketilen yıllık dizel yakıtı (L);
E_2 : Dizelin enerji değeri (MJ L^{-1});
G : Kullanılan gübre miktarı (kg);
E_3 : Gübrelerin enerji katsayısı (MJ kg^{-1});
ME : Makine enerjisi (MJha-1).
DV : Dane verimi (kg ha^{-1})
EE : Enerji eşdeğeri (MJ kg^{-1})
SV : Saman verimi (kg ha^{-1})
SU : Suluda $EÇ_T$
YA : Yağışa dayalı $EÇ_T$
TSM: Toplam sulama suyu miktarı (m^{3}ha^{-1}).

Çevresel Kirliliğin Değerlendirilmesi

Farklı tamamlayıcı sulama rejimleri altında buğday üretiminin çevre kirliliği üzerindeki etkisini belirlemek için sera gazı (GHG) emisyon değerlendirmesi yapılmıştır. Farklı sulama rejimi uygulamaları için toplam sera gazı emisyonları, tarım makineleri, dizel yakıtı, elektrik ve gübreler de dahil olmak üzere her üretim faaliyeti için sera gazı emisyonların ayrı ayrı hesaplanmasıyla elde edilmiştir. Farklı ölçü birimleri dikkate alınarak, toplam tarımsal girdilere ilişkin sera gazı emisyonları, literatürden temin edilerek Çizelge 5'de sunulan GHG emisyon eşdeğerleri kullanılarak, ortak bir CO_2 eşd (karbondioksit eşdeğeri) sisteminde hesaplanmıştır.

Bitkisel üretim esnasında karbondioksit (CO_2) ve CO_2 olmayan gazlar (N_2O, CH_4) gibi sera gazları üretilmekte ve bu da atmosferin doğal sera etkisini artırmaktadır. Ancak bitkiler fotosentez yoluyla havadaki CO_2'yi kullanarak, atmosferik CO_2'nin azaltılmasına vesile olmaktadır. Bu çalışmada, farklı sulama rejimleri altındaki buğday üretiminin sezonluk CO_2 kullanım miktarları tahmini olarak hesaplanmıştır. Bu bağlamda, ürünün (dane +saman) kuru maddesindeki karbon miktarı Çizelge 5'de verilen değere göre hesaplanmış, belirlenen karbon miktarı, CO_2/C (44/12) oranı ile çarpılarak, fotosentezde kullanılan sezonluk CO_2 miktarı tahmin edilmeye çalışılmıştır.

Çizelge 1. Tamamlayıcı sulama konuları ve sulama programlarına ilişkin bilgileri
Table 1. Information on supplemental irrigation treatments and irrigation programs

Sulama Rejimleri	SK dönemi		BŞ Dönemi		SO Dönemi		Toplam Sulama Suyu(mm)
	Sulama Zamanı	Sulama Miktarı (mm)	Sulama Zamanı	Sulama Miktarı (mm)	Sulama Zamanı	Sulama Miktarı (mm)	
TTS	14.04.2019	81,5	13.05.2019	117,6	28.05.2019	119,4	318,5
	13.04.2020	78,3	15.05.2020	121,8	27.05.2020	123,4	323,5
KTS-1	14.04.2019	90	13.05.2019	90	28.05.2019	90	270
	13.04.2020	90	15.05.2020	90	27.05.2020	90	270
KTS-2	14.04.2019	70	13.05.2019	70	28.05.2019	70	210
	13.04.2020	70	15.05.2020	70	27.05.2020	70	210
KTS-3	14.04.2019	50	13.05.2019	50	28.05.2019	50	150
	13.04.2020	50	15.05.2020	50	27.05.2020	50	150
Y	-	-	-	-	-	-	-

Çizelge 2. İki yıl ortalaması olarak gerçekleşen sulama suyu kısıntı oranları
Table 2. As average of two years, irrigation water deficit rates

Sulama Rejimleri	SK Dönemi Kısıntı Oranı (%)	BŞ Dönemi Kısıntı Oranı (%)	SO Dönemi Kısıntı Oranı (%)	Toplamda Kısıntı Oranı (%)
TTS	0,0	0,0	0,0	0,0
KTS-1	0,0	24,8	25,8	15,9
KTS-2	12,5	41,5	42,3	34,6
KTS-3	37,5	58,2	58,8	53,3

Çizelge 3. Tarım makinaları, teknik özellikleri ve kullanım bilgileri
Table 3. Agricultural machinery, technical specifications and usage information

Makine Kullanımı	Ağırlığı (kg)	Faydalı Ömrü(h)*	İş Kapasitesi (h ha^{-1})
Traktör	3396	16000	8,17
Pulluk	687	2000	3,5
Kazayağı (Kültivatör)	585	2000	1,30
Kombi kürüm	550	2000	1,2
Mibzer	1066	1500	1,5
Merdane	1000	2000	0,67

*ASAE (2000)

Çizelge 4. İki yıl ortalaması sulama suyu miktarları ve ürün verim değerleri
Table 4. Irrigation water amounts and crop yield values as average of two years

Sulama Rejimleri	Sulama Suyu Miktarı (mm)	Sezonluk Su Tüketimi (mm)	Dane Verimi (kg ha^{-1})	Saman Verimi (kg ha^{-1})	Biyolojik Verim (kg ha^{-1})
TTS	321	568,5	7918	13557	21475
KTS-1	270	518,7	7688	12870	20558
KTS-2	210	459,3	7660	12148	19808
KTS-3	150	408	7285	12107	19392
Y	0.0	259,5	3508	12050	15558

Çizelge 5. Üretim girdileri ve çıktılarına ilişkin enerji katsayıları ile seragazı emisyon faktörleri
Table 5. Energy coefficients and greenhouse gas emission factors related to production inputs and outputs

	Enerji Eşdeğeri	Kaynaklar	Sera Gazı Emisyon Faktörü	Kaynaklar
A-Üretim girdileri				
Elektrik	10,28 MJ kWh^{-1}	Acaroğlu (2001)	0,55 $kgCO_2$eşd kWh^{-1}	K1
Dizel yakıtı	40,68 MJ L^{-1}	Boustead (2003)	2,76 $kgCO_2$eşd L^{-1}	K2
Azot (N)	38,7 MJ kg^{-1}	Tzilivakis ve ark. (2005)	7,759 $kgCO_2$eşd kg^{-1}	K3
Fosfor (P_2O_5)	12 MJ kg^{-1}	Tzilivakis ve ark. (2005)	2,332 $kgCO_2$eşd kg^{-1}	K3
Makineler	49,35 MJ kg^{-1}	Hacıseferoğulları ve Acaroğlu (2015)	0,071 $kgCO_2$eşd MJ^{-1}	K4
Traktör	71,38 MJ kg^{-1}	Acaroğlu ve Aksoy (2005)	0,071 $kgCO_2$eşd MJ^{-1}	K4
B-Ürünler			Karbon (C) içeriği	
Dane	14,7 MJ kg^{-1}	Devasenapathy ve ark. (2009)	0,45 kg C kg^{-1} (KM)	K5
Saman	12,5 MJ kg^{-1}	Devasenapathy ve ark. (2009)	0,45 kg C kg^{-1} (KM)	K5

KM: Kuru madde; K1: Dulkadiroğlu (2018), K2: Dyer ve Desjardins (2003); K3: Chen ve ark (2015); K4: Dyer ve Desjardins (2006); K5: Epstein ve Bloom (2005); Bolinder ve ark. (2007)

Çizelge 6. Sulama rejimleri altında buğday üretiminde gerçekleşen enerji tüketimleri
Table 6. Energy consumption in wheat production under irrigation regimes

Sulama Rejimleri	Elektrik (MJ ha^{-1})	Dizel Yakıtı (MJ ha^{-1})	Azot (MJ ha^{-1})	Fosfor (P_2O_5) (MJ ha^{-1})	Tarım Makineleri (MJ ha^{-1})	Toplam Enerji Tüketimi (MJ ha^{-1})
TTS	16205	5492	6192	1200	274	29363
KTS-1	13600	5492	6192	1200	274	26758
KTS-2	10629	5492	6192	1200	274	23787
KTS-3	7586	5492	6192	1200	274	20744
Y	0.0	5492	6192	1200	274	13158

Araştırma Sonuçları ve Tartışma

Enerji Tüketimi

Farklı buğday üretim sistemlerine ilişkin toplam enerji girdileri, her tamamlayıcı sulama rejimi için işgücü, yakıt, makine, elektrik ve gübre ile ilgili enerji tüketimi tahmini olarak hesaplanarak sonuçları Çizelge 6'da verilmiştir. Sulama rejimlerinin tümü için, en yüksek enerji tüketimi elektrik, gübre ve dizel yakıtı gibi girdilerden oluşmaktadır.

Buğday üretiminde farklı tamamlayıcı sulama rejimleri karşılaştırılması, en yüksek toplam enerji tüketiminin (29363 MJ ha^{-1}) buğdayın üç gelişme döneminde toprak nemine dayalı TTS kontrol uygulamasında olduğunu göstermiştir. Kontrol TTS konusu ile karşılaştırıldığında, KTS-1, KTS-2, KTS-3 rejimleri altında enerji tüketimi daha düşüktür. Buğdayın SK, BŞ ve SO dönemlerinde eşit 90 mm sulama suyu uygulanan KTS-1 rejiminde, toplam enerji tüketimi (26758 MJ ha^{-1}) TTS'ye göre yaklaşık %8,9 daha düşük gerçekleşmiştir. Diğer KTS-2 ve KTS-3 sulama rejimlerinde toplam enerji tüketimi sırasıyla 23787 ve 20744 MJ ha^{-1} olarak gerçekleşmiştir. Bu sonuçlar diğer yazarlarınkilerle tutarlıdır. Sözgelimi, Taki ve ark (2018b) İran'da buğday üretimi için toplam enerji tüketimini; yağışa dayalı sistemde 9350 ve suluda 23410 MJ ha^{-1}, Safa ve Samarasinghe (2011) Yeni Zelanda'da bu değerleri sırasıyla 17450 ve 25600 MJ ha^{-1} olarak belirlemişlerdir. Bu çalışmada en düşük enerji tüketimi 13158 MJ/ha ile

yağışa dayalı buğday üretim sisteminde gerçekleşmiştir. Düşük enerji tüketiminin tek nedeni sulama yapılmamış olması sebebiyle elektrik tüketilmemesidir. Diğer araştırıcılar da toplam enerji tüketiminde sulama işlemenin rolüne dikkat çekmişlerdir. Örneğin Ghorbani ve ark (2011) geleneksel tam sulamalı buğday üretiminde toplam enerji tüketiminin 45370 MJ ha^{-1}, yağışa dayalı buğday üretiminde ise 9350 MJ ha^{-1} olduğunu rapor etmişlerdir. Failla ve ark (2020) Güney İtalya'da yağışa dayalı buğday üretiminin toplam enerji tüketimini 13300 MJ ha^{-1} olarak bildirmişlerdir.

Enerji Verimlilik Analizi

Farklı tamamlayıcı sulama rejimlerine dayalı buğday tarımına ilişkin Çizelge 4'de sunulan veriler incelendiğinde, dane verimi yönünden KTS-1 (7688 kg ha^{-1}) ve KTS-2 (7660 kg ha^{-1}) arasında bir fark bulunmazken, sulama suyu yönünden KTS-2'nin 60 mm tasarruf sağladığı görülmektedir. Dolayısıyla KTS-2 rejimi KTS-1 rejiminin üstünüdür ve bölge koşullarında buğday tarımında KTS-1 uygulamasına yer olmadığını göstermektedir. En yüksek dane verimine sahip TTS rejimi ile kıyaslandığında, KTS-2 rejimi dane verimini %3,2 düşürürken, sulama suyundan %34,6 (111 mm) tasarruf sağlamaktadır. Benzer şekilde KTS-3 rejimi de dane verimini sadece %8 azaltırken, sulama suyundan %53,3 (171 mm) tasarruf sağlamaktadır. Bu hususlar birlikte değerlendirildiğinde, TTS, KTS-2 ve KTS-3 rejimleri altında buğday yetiştiriciliği, enerji performansları yönünden iyi bir analize ihtiyaç duymaktadır.

Enerji verimlilik değerlendirmesine esas teşkil eden toplam enerji girdisi ile üretilen toplam enerji değerleri Çizelge 7'de verilmiştir. Çizelge 7'den görüleceği gibi, enerji üretimi hem dane bazında (116395 $MJha^{-1}$) ve hem de biyolojik kütle bazında (285857 $MJha^{-1}$) en yüksek TTS rejiminde ve en düşüğü ise yağışa dayalı buğday üretim sisteminde sırasıyla 51567 ve 202192 MJ ha^{-1} gerçekleşmiştir. Kısıntılı tamamlayıcı sulama rejimlerinden KTS-1 ile KTS-2'nin dane kaynaklı enerji üretimleri arasında bir fark bulunmazken, KTS-2'de saman kaynaklı üretilen enerji miktarı %5,6 daha düşüktür. Yukarıda da zikredildiği gibi, KTS-1'e göre KTS-2 60 mm su tasarrufu sağladığından ve çok kısıtlı su kaynaklarına sahip bu bölge için KTS-2, KTS-1'in üstünüdür. Tanık TTS rejimi ile karşılaştırıldığında, KTS-2 ve KTS-3 rejimleri altında $EÇ_D$ sırasıyla %3,3 ve %8 ve $EÇ_T$ sırasıyla, %7,5 ve %9,6 daha düşüktür. Buna karşılık yine TTS ile kıyaslandığında, KTS-2 ve KTS-3 rejimleri sulama suyundan sırasıyla %34,6 ve 53,3 gibi büyük oranda tasarruf sağlamaktadır. Bu sonuçları üretim artışı ve su tasarrufu olmak üzere iki açıdan değerlendirmek mümkündür (Çizelge 8). Çizelge 8'de görüldüğü gibi amaç üretimi artırmak ise, TTS rejiminde uygulanan 321 mm sulama suyu, KTS-2 rejimi ile uygulanırsa, yaklaşık 1,53 birim (ha) alan sulanarak, dane üretimi 11704 kg'a, toplam enerji üretimi ($EÇ_T$) de 404082 MJ'e çıkarılabilir. Benzer şekilde KTS-3 rejimi ile uygulandığında, yaklaşık 2,14 birim (ha) alanda üretim yapılarak, dane üretimi 15590 kg'a ve toplam enerji çıktısı ($EÇ_T$) ise 611733 MJ'e artırılabilir. Sudan tasarruf öncelikli ise, TTS rejimi altında üretilen dane ve eşdeğeri enerji miktarları, KTS-2 rejiminde yaklaşık 1.034 birim (ha) ve KTS-3 rejiminde ise yaklaşık 1,09 birim (ha) alandan üretilebilecektir. Bu durumda TTS ile karşılaştırıldığında, sulama suyunda, KTS-2 rejiminde %32,4 ve KTS-3 rejiminde %49 tasarruf sağlanabilecektir.

Farklı tamamlayıcı sulama rejimleri altında yetiştirilen buğdayın enerji verimlilik göstergelerine ilişkin veriler Çizelge 9'da verildiği gibidir. Çizelge 9'dan görüldüğü gibi en yüksek dane verimi ve enerji çıktısı TTS uygulamasında gerçekleşmesine rağmen, sulama rejimleri arasında KTS-3 rejiminde 12,46 gibi biraz daha iyi bir enerji verimliliği oranı gözlenirken, en kötü oran 9,74 ile TTS uygulamasında gerçekleşmiştir. Enerji verimlilik oranı, hektar başına, buğdayı yetiştirmek için ne kadar enerji tüketildiğini ve ne kadar enerji üretildiğini gösterir. Aynı derecede önemli olan diğer enerji göstergeleri enerji üretkenliği ve sulamanın enerji üretkenliğidir. Tamamlayıcı sulama rejimleri arasında EÜ performansı KTS-3 rejiminde 0,935 $kgMJ^{-1}$ ile en yüksek ve TTS rejiminde ise 0,731 $kgMJ^{-1}$ ile en düşüktür. Bu gösterge, buğday üretiminde tüketilen 1 MJ enerjiye karşılık kg cinsinden üretilen biyolojik verimi göstermektedir. Sulama rejimleri altında gerçekleşen SEÜ gösterge değerleri 26,06 MJm^{-3} ile 37,49 MJm^{-3} arasında değişmiş olup, en iyi performansı KTS-3 rejimi göstermiştir.

Çizelge 7. Konuların enerji girdileri ve enerji çıktıları
Table 7. Energy inputs and energy outputs of treatments

Sulama Rejimleri	EG (MJ ha^{-1})	Dane Verimi (kg ha^{-1})	$EÇ_D$ (MJ ha^{-1})	Saman Verimi (kg ha^{-1})	$EÇ_S$ (MJ ha^{-1})	$EÇ_T$ (MJ ha^{-1})
TTS	29363	7918	116395	13557	169462	285857
KTS-1	26758	7688	113014	12870	160895	273889
KTS-2	23787	7660	112602	12148	151850	264452
KTS-3	20744	7285	107090	12107	151337	258427
Y	13158	3508	51567	12050	150625	202192

EG: Tüketilen enerji ($MJha^{-1}$); $EÇ_D$ =Dane kaynaklı enerji üretimi ($MJha^{-1}$); $EÇ_S$ = Saman kaynaklı enerji üretimi ($MJha^{-1}$); $EÇ_T$ = Toplam enerji çıktısı ($MJha^{-1}$).

Çizelge 8. Sulama rejimlerinin ürün ve su kazancı yönünden analizi
Table 8. Analysis of irrigation regimes in terms of yield and water gain

Sulama Rejimleri	USS	Amaç: Üretimi Artırmak			Amaç: Su Tasarrufu Sağlamak		
		SA	DÜ	$EÇ_T$	TTS	SSİ	SST
TTS	321	1,0	7918	285857	1.0	321	0,0
KTS-2	210	1,53	11704	404082	1.034	217,1	32,4
KTS-3	150	2,14	15590	611733	1.090	163,5	49

USS: Uygulanan Sulama Suyu (mm); SA: Sulanabilecek Alan (ha); DÜ: Dane Üretimi (kg); TTS: TTS Eşdeğeri Dane Üretim Alanı (ha); SSİ: Sulama Suyu İhtiyacı (mm); SST: Sağlanan Su Tasarrufu (%)

Çizelge 9. Enerji verimlilik göstergeleri
Table 9. Energy efficiency indicators

Sulama Rejimleri	Dane + Saman			
	NEV (MJ ha^{-1})	EÜ (kg MJ^{-1})	SEÜ (MJ m^{-3})	EVO
TTS	256469	0,731	26,06	9,74
KTS-1	247131	0,768	26,55	10,24
KTS-2	240665	0,833	29,65	11,12
KTS-3	237683	0,935	37,49	12,46
Y	189034	1,182	-	15,36

NEV: net enerji verimi(MJha^{-1}); EÜ: Enerji üretkenliği (kgMJ^{-1}); SEÜ: Sulama enerji üretkenliği (MJ m^{-3})

Çizelge 10. Sulamanın enerji tüketimine etkisi
Table 10. Effect of irrigation on energy consumption

Sulama Rejimleri	Sulamada Enerji Tüketimi (MJ ha^{-1})	Sulamada Nispi Enerji Azalışı (%)	Toplam Enerji Tüketimi (MJ ha^{-1})	Sulama Enerjisi Payı (%)
TTS	16205	0,0	29363	55,19
KTS-1	13600	16,07	26758	50,82
KTS-2	10629	34,41	23787	44,68
KTS-3	7586	46,81	20744	36,57
Y	-	-	13158	-

Çizelge 11. Konuların GHG emisyonları (kg CO_2eşd ha^{-1})
Table 11. GHG emissions of the irrigation regimes (kg CO_2eq ha^{-1})

Sulama Rejimleri	Elektrik	Dizel Yakıtı	Azot	Fosfor (P_2O_5)	Traktör ve Makine	Toplam GHG Emisyonu
TTS	869,6	372,6	1241,4	233,2	19,5	2736,3
KTS-1	727,6	372,6	1241,4	233,2	19,5	2594,1
KTS-2	568,7	372,6	1241,4	233,2	19,5	2435,2
KTS-3	406	372,6	1241,4	233,2	19,5	2272,5
Y	0,0	372,6	1241,4	233,2	19,5	1866,5

Çizelge 12. Buğday üretiminde kısıntılı tamamlayıcı sulamanın çevresel etki azaltım potansiyeli
Table 12. Environmental impact reduction potential of deficit supplementary irrigation in wheat production

Sulama Rejimleri	SKS	TTS-1	TTS-2	TTS-3	TTS-4
TTS	869,6	1,00	869,6	2736,3	0,0
KTS-2	568,7	1,034	588,04	2454,5	10,3
KTS-3	406	1,090	442,54	2309	15,6

SKS: Sulama Kaynaklı GHG Salımı (kgCO_2 eşd ha^{-1}); TTS-1: TTS Eşdeğeri dane verimi (7918 kg) için gerekli üretim alanı (ha); TTS-2: TTS eşdeğeri ürün için sulamanın GHG salımı (kgCO_2 eşd ha^{-1}); TTS-3: TTS eşdeğeri ürün için Toplam GHG salımı (kgCO_2 eşd ha^{-1}); TTS-4: TTS konusuna göre çevresel etki azaltım oranı (%)

Sulamanın Enerji Tüketimine Etkisi

Çalışma kapsamında elektrik tüketimi, yeraltı suyu ile sulamada gerçekleşmiştir. Özellikle bu havzada, sulama suyu yeraltı sularından elektrikli derin kuyulardan pompalanmaktadır. Bu bölgedeki ciddi sorunlardan biri de aşırı tüketim nedeniyle yeterli suyun bulunamamasıdır. Dolayısıyla bu bölgede buğday üretiminde en büyük enerji tüketen kaynaklardan biri, elektrikli pompalarla su pompalamak ve sulama işlemini gerçekleştirmek için ihtiyaç duyulan elektriktir. Özetlenen elektrik tüketimi sonuçları, buğday üretiminde, farklı tamamlayıcı sulama işlemlerinin uygulanmasının elektrik tüketimi üzerinde güçlü bir etkiye sahip olduğunu göstermektedir. TTS uygulaması, hektar başına 3200 m^3 sulama suyunun terfisi ve tarlaya uygulamasında yaklaşık 1581 kWh ha^{-1} elektrik tüketmiştir (Çizelge 4). Tamamlayıcı sulamada sulama suyu miktarını azaltarak, sulamada tüketilen toplam elektrik tasarrufu %16.3'den (KTS-1) %53.3'e (KTS-3) artırılabilir. Buğday yetiştiriciliğinde en düşük elektrik tüketimi (738 kWh ha^{-1}) KTS-3 rejiminde gerçekleştir. Diğer sulama rejimleri ile karşılaştırıldığında, KTS-3 rejimi altında elektrik tüketimi önemli ölçüde (1,40 ila 2,14 kat) daha düşüktür.

Sulama suyu derin kuyudan temin edilerek doğrudan damla sulama sistemine verilmiştir. Bu çalışma kapsamında belirtilen elektrik, sulama suyu temini ve sulama işleminde tüketilmiştir. Sulama rejimleri altında, sulamada ve toplamda tüketilen enerjilerin miktarları Çizelge 10'da verildiği gibidir. Bu verilere göre, sulama işleminin tüketilen toplam enerji içindeki payı, sulama rejimine göre farklı olup, %36,57 (KTS-3) ile %55,19 (TTS) arasında değişmektedir. Tamamlayıcı sulama suyu miktarları azaldıkça, sulama enerjisinin payı da azalmaktadır. Bununla birlikte, TTS ve KTS-1 rejimlerinde sulamada tüketilen enerji miktarı, buğday üretiminde tüketilen toplam enerjinin yarısından fazlasını oluşturmuştur. Bu sonuçlar, sulu buğday tarımında, sulamanın önemli ölçüde enerji tüketen bir faaliyet olduğunu göstermektedir.

Bu çalışmanın sonuçları, buğday üretiminde, sulamanın elektrik ve elektrik kaynaklı enerji tüketimini azaltılasının mümkün olduğunu göstermektedir. Bu bağlamda, sulamada enerji tüketimi ve dane verimi en yüksek olan TTS rejimi yerine, KTS-3 rejimi uygulaması ile aynı dane verimi 1,09 birim (hektar) alandan üretilebilirken, sulama enerji tüketimi de 8269 MJ (7586 MJ × 1,09 = 8269 MJ) olmaktadır. Bu durumda da TTS rejimi (16205 $MJha^{-1}$) ile kıyaslandığında, dane üretiminde bir azalma olmadan KTS-3 rejimi ile sulamada enerji tüketimi %48,97 [(16205-8269 / 16205)×100] azaltılabilecektir.

Çevresel Etki Analizi

Tarım sektörü çevreyi kirleten sektörlerden biri olduğundan, farklı tamamlayıcı sulama uygulamaları altında buğday yetiştirmeye ilişkin çevresel göstergelerin ölçülmesi ve çevre üzerindeki etkisinin belirlenmesi önem arz etmektedir. Farklı sulama rejimleri altında yapılan buğday tarımından kaynaklanan sera gazı emisyonları hesaplanarak Çizelge 11'de verilmiştir. Sera gazı emisyonlarının değerlendirilmesi, buğdayın TTS rejimi altında yetiştirildiği durumda emisyonların en yüksek olduğunu (2736 $kgCO_2$ eşd ha^{-1}) ve yağışa dayalı sistemde ise en düşük olduğunu (1866 $kgCO_2$eşdha^{-1}) göstermiştir. Azaltılmış su ile tamamlayıcı sulama uygulamaları, sera gazı emisyonlarının azalmasına bağlı olarak çevre kirliliği üzerinde olumlu bir etkiye sahip olduğu görülmektedir.

Bireysel sulama rejimleri ve diğer üretim materyallerinin çevre kirliliği üzerindeki etkisinin analizi, sera gazı emisyonlarının en büyük oranının azotlu gübre (TTS %45,3 - Y %66,5), sulama elektriği (KTS-3 % 17,87 – TTS %31,8) ve dizel yakıtı (TTS %13,63 – Y %19,77) ile ilgili olduğunu göstermiştir.

Dane verimi yönünden KTS-1 (7688 kg ha^{-1}) ve KTS-2 (7660 kg ha^{-1}) arasında bir fark bulunmazken, sulama suyu yönünden KTS-2 60 mm tasarruf sağlamaktadır. Dolayısıyla KTS-2 rejimi KTS-1 rejiminin üstünüdür. En yüksek dane verimine sahip TTS rejimi ile kıyaslandığında, KTS-2 rejimi dane verimini %3,2 düşürürken, sulama suyundan %34,6 tasarruf sağlamaktadır. Benzer şekilde KTS-3 rejimi de dane verimini sadece %8 azaltırken, sulama suyundan %53,3 tasarruf sağlamaktadır. Bu hususlar birlikte değerlendirildiğinde, TTS, KTS-2 ve KTS-3 rejimleri altında buğday yetiştiriciliği iyi bir enerji performansı gösterse de, çevresel değerlendirme yalnızca bir üretim sisteminin (KTS-3) diğer sulama rejimleri ile karşılaştırıldığında önemli ölçüde daha düşük çevre kirliliğine sahip olduğunu göstermektedir.

Farklı tamamlayıcı sulama rejimleri altında yapılan buğday tarımında, sulama harici tüm üretim girdileri ve miktarları aynı olduğundan, sera gazı emisyonunu etkileyen tek faktör sulamada kullanılan elektrik miktarıdır. Özellikle verim ve enerji performansı en iyi olan TTS rejimi yerine, KTS-2 ve KTS-3 rejimleri ile aynı verim ve enerji performansının elde edilmesi yoluna gidilmesi, sera gazı salımlarını azaltabilecektir. Şöyle ki; KTS-2 rejimi ile 1,034 birim (ha) alanda ve KTS-3 rejimi altında ise 1,09 birim (ha) alanda buğday yetiştirilmesi, TTS rejimine eşdeğer dane verimini ve enerji üretimini sağlayacaktır (Çizelge 12). Bu durumda Çizelge 12'de görüleceği üzere, TTS rejimi ile karşılaştırıldığında, üretim alanı KTS-2 rejimi altında %3.4 veya KTS-3 rejimi altında %9 artırılması koşulunda, dane ve enerji üretiminde bir azalma olmadan, sera gazı salımı sırasıyla %10,3 ve %15,6 azaltılabilecektir.

Bilindiği üzere, bitkisel üretim hem bir enerji kullanıcısı hem de bir enerji üretici sistemdir. Bitkiler, biyokütle üretmek için güneş enerjisini için kullanırken, ana karbon kaynağı olarak atmosferik karbondioksiti (CO_2) kullanmaktadır. Yani bitkisel üretim atmosferdeki CO_2'yi bu yolla azaltmaktadır. Tarım, güneş enerjisini biyokütleye dönüştüren ve bu da insanlara ve hayvanlara enerji sağlayan mahsuller yetiştirerek enerji sağlar. Farklı sulama rejimleri altında gerçekleşen buğday üretimlerinin bu yolla kullandıkları mevsimlik CO_2 miktarları tahmini olarak hesaplanmıştır. Hesaplamalara göre, buğday bitkisi hektar başına TTS, KTS-2, KTS-3 ve yağışa dayalı sistemde sırasıyla 34.4, 32.7, 32 ve 25.7 ton atmosferik CO_2'nin kullanıldığı kestirimi yapılmıştır. Buradan da görüldüğü gibi, buğday üretimi, üretim girdilerinin neden olduğu CO_2 eşdeğeri sera gazı emisyon miktarının, katbekat üzerinde atmosferik CO_2'yi etkisiz hale getirmektedir.

Sonuç

- Genel olarak, bu çalışma buğday üretiminde uygulanan tamamlayıcı sulama seviyesinin çevre kirliliği ve enerji kullanım verimliliği üzerinde bir etkiye sahip olduğunu göstermiştir. Buğdayın kritik dönemlerinde sulanması yoluyla sulamanın ve sulama suyu miktarının azaltılmasıyla, buğday verimi üzerinde önemli bir etki olmaksızın elektrik tüketimi, enerji tüketimi ve çevre kirliliği üzerinde olumlu etkiler bulunmuştur.
- Buğday üretiminde kısıntılı tamamlayıcı sulama uygulamaları, toprak nemine dayalı tamamlayıcı sulamaya (TTS) göre %34,6 (KTS-2) ile %53,3 (KTS-3) arasında daha az elektrik ve %18,99 (KTS-2) ile %29,35 (KTS-3) arasında daha az enerji tüketilmiştir.
- Bu çalışmanın sonuçları tamamlayıcı sulamalı buğday üretiminde en yüksek enerji verimliliği oranının KTS-3 (12,46) uygulamasında bulunduğunu göstermektedir. En yüksek toplam enerji tüketimi (29363 MJ ha^{-1}) ve en yüksek enerji çıktısı ise (285857 MJ ha^{-1}) TTS rejiminde elde edilmiştir. Ayrıca, sulama rejimleri arasında en iyi EÜ (0,935 kg MJ^{-1}) ve en yüksek SEÜ değeri (37,49 MJ m^{-3}) KTS-3 rejiminde elde edilmiştir.
- Miktarı azaltılmış tamamlayıcı sulama, çevre kirliliğini azaltmaya katkıda bulunabilecek önemli bir stratejidir. Bulgularımız, buğday üretimindeki en yüksek GHG emisyonlarının (2736,3 $kgCO_2$ eşd ha^{-1}) geleneksel tam tamamlayıcı sulama ile ilişkili olduğunu göstermiştir. Kısıntılı tamamlayıcı sulama usulü ile sulama suyu yönetimini iyileştirerek, önemli ölçüde su tasarrufu sağlamak ve suluda buğday üretim alanını kısmen artırmak mümkündür. Bu yolla toprak nemine dayalı tam tamamlayıcı sulamayı terk etmek, GHG emisyonlarını %10,3'den (KTS-2) %15,6'ya (KTS-3) kadar azaltabilir.

Beyanlar

Yazar Katkısı

Mehmet Ali Dündar: Araştırmanın planlanması, tarla denemesinin yürütülmesi, tarla deneme verilerinin elde edilmesi, makalenin hazırlanması. Havva Nur Demir Deveci: Makalenin planlanması, literatüre dayalı verilerin toplanması, tarla ve literatür kaynaklı verilerin işlenmesi, makale taslağının oluşturulması, makalenin hazırlanması. Ramazan Topak: Araştırmanın ve makalenin planlanması, literatüre dayalı verilerin toplanması, tarla ve literatür kaynaklı verilerin işlenmesi, makalenin hazırlanması.

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Exploring the Antioxidant and Neuroprotective Potential of *Muscari armeniacum*: Phenolic Profiling and Enzyme Inhibition

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ABSTRACT

This study aimed to investigate the antioxidant and enzyme inhibitory properties of Muscari armeniacum, a plant native to Türkiye, which is known for its bioactive compound content. Ethanol extracts of Muscari armeniacum were prepared and analyzed using a variety of bioanalytical methods to assess its potential health-promoting properties. The antioxidant capacity was evaluated through Fe^{3+}-Fe^{2+} reduction capacity, CUPRAC, DPPH, and ABTS radical scavenging activities. Additionally, the total phenolic and flavonoid contents of the extracts were determined, as these compounds are critical indicators of antioxidant potential. The antioxidant activity of *Muscari armeniacum* was compared with five standard antioxidants commonly used for benchmarking: BHA, α-tocopherol, BHT, trolox, and ascorbic acid. The extract demonstrated a high flavonoid content (23.24 µg QE/mg extract) and a significant amount of phenolics (14.38 µg GAE/mg extract), with the flavonoid content being particularly noteworthy. In addition to its antioxidant properties, the enzymatic activity assays revealed that the extract significantly inhibited acetylcholinesterase (AChE) and butyrylcholinesterase (BChE) enzymes, which are associated with neurodegenerative diseases such as Alzheimer's. The IC_{50} values were determined to be 54.14 mg/mL (R^2 = 0.9695) for AChE and 58.73 mg/mL (R^2 = 0.9609) for BChE, indicating moderate enzyme inhibition. These results suggest that *Muscari armeniacum* could serve as a valuable source of bioactive compounds with significant antioxidant and enzyme inhibitory activities. Its potential applications in the treatment of oxidative stress-related diseases and neurodegenerative disorders make it a promising candidate for further pharmacological studies. This research underscores the importance of exploring native plants for their medicinal and therapeutic potential, contributing to the development of alternative treatments for challenging health conditions.

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Introduction

Free iron is necessary for several physiological processes in living things, including DNA synthesis, oxygen transport, ATP synthesis, and chlorophyll synthesis. However, by producing reactive oxygen species (ROS), free iron can potentially present serious threats to cellular health

These ROS, in turn, can cause oxidative damage to critical biomolecules such as DNA, lipids, and proteins, often leading to lipid peroxidation and DNA damage (Topal et al., 2021). The accumulation of ROS in tissues further exacerbates this damage, negatively impacting lipids, proteins, carbohydrates, and DNA integrity. Certain environmental factors, such as excessive heating of organic materials, can accelerate ROS production, which explains the high levels of free radicals found in cigarette smoke (Özler et al., 2023).

Organisms that rely on oxygen for survival have developed intricate antioxidant defense systems to mitigate the detrimental effects of ROS. These systems repair damaged molecules and eliminate those that cannot be salvaged, thus reducing oxidative stress. Antioxidant enzymes are at the core of these systems, working in tandem to maintain cellular integrity. In the food industry, natural antioxidants, including specific enzymes, are increasingly employed to minimize ROS and prevent lipid peroxidation in food products. The relevance of antioxidants for human health lies in their chemical diversity, solubility, and availability from natural sources, underscoring the importance of encouraging their consumption through diet (Topal et al., 2021).

Natural antioxidants are organic compounds synthesized by plants, with phenolic compounds standing out for their pronounced health benefits. Phenolic compounds, when ingested through dietary sources, exert positive effects on the body by scavenging free radicals and reducing oxidative damage. In recent years, there has been a notable increase in the use of plant-derived antioxidants in the food industry, reflecting their potential to enhance food quality and safety. When antioxidant defense systems weaken, cellular damage escalates, potentially leading to programmed cell death. Antioxidants, by neutralizing free radicals, play a pivotal role in preventing such adverse outcomes, making their regular intake essential for maintaining health (Topal & Kocabaş, 2024).

Muscari armeniacum, commonly referred to as the Armenian grape hyacinth, is a plant species native to the Eastern Mediterranean. It is widely distributed across regions spanning Greece, Türkiye, the Caucasus, and Armenia (Bokov, 2019). Renowned for its vibrant blue blooms and unique aesthetic appeal, *Muscari armeniacum* is highly valued by plant enthusiasts and landscape designers alike. Beyond its ornamental value, the plant serves as an exceptional honey source, attracting bees, butterflies, and bumblebees with its pleasant fragrance (Bokov, 2019). The striking blue coloration of *Muscari armeniacum* flowers is attributed to the presence of anthocyanins, with p-coumaric acid identified as one of the acyl groups in muscarinin A, a complex anthocyanin structure (delphinidin-3-(6-p-coumaroylglucoside)-5-(4-rhamnosyl-6-malonylglucoside)) (Yoshida et al., 2002). Additionally, the plant's bulbs have been studied for their involvement in the hormonal regulation of gummosis, with a particular focus on the chemical composition of their polysaccharide-rich gums (Miyamoto et al., 2010).

Despite its aesthetic and ecological significance, research on *Muscari armeniacum* remains limited, particularly concerning its chemical composition and pharmacological potential. Given its widespread use and unique bioactive properties, there is a need for more comprehensive studies to explore its potential applications in medicine and industry. This study aims to fill this gap by investigating the biological activities of *Muscari armeniacum*, including its antioxidant and enzyme inhibitory properties, to provide insights into its possible medicinal significance. By enhancing our understanding of this species, the research seeks to highlight its potential as a valuable source of natural antioxidants and therapeutic agents.

Material and Methods

Material

Muscari armeniacum was collected during May-June 2022 from the valley of Ozanlar Village in Ağrı Province, at coordinates approximately 39.774153, 43.043444. The plant's flowers were sun-dried and cleaned of dust before undergoing analysis. For extraction, the dried flowers were crushed using a blender and mixed with 50 mL of ethanol. The mixture was left to stir overnight at room temperature on a magnetic stirrer. Following this, the solution was filtered through Whatman No.1 filter paper, and the ethanol was evaporated using a rotary evaporator to obtain the dry extract.

Methods

Cu^{2+}-Cu^{+} reduction capacity

A slightly modified version of the method described by Apak et al. (2006) was employed. In this procedure, 0.125 mL of $CuCl_2$ solution (0.01 M), 0.125 mL of ethanolic neocuproine solution (7.5×10^{-3} M), and 0.125 mL of CH_3COONH_4 buffer solution (1 M) were added to test tubes. Subsequently, ethanol extracts of *Muscari armeniacum* at various concentrations were introduced into the tubes. The final volume of each mixture was adjusted to 1 mL using distilled water. After a 30-minute incubation, the absorbance of the samples was measured at 450 nm against a blank solution prepared with distilled water.

Fe^{3+}-Fe^{2+} reduction capacity

The method was performed following the procedure described by Oyaizu (1986). Initially, a stock solution with a concentration of 1 mg/mL was prepared. Aliquots of this stock solution were transferred to test tubes at varying concentrations, and the volume was adjusted to 0.75 mL with distilled water. Next, 1 mL of 0.2 M phosphate buffer (pH 6.6) and 1 mL of 1% potassium ferricyanide [$K_3Fe(CN)_6$] were added to each tube. The mixtures were then incubated at 50°C for 20 minutes. Subsequently, 1 mL of 10% trichloroacetic acid (TCA) and 0.25 mL of 0.1% $FeCl_3$ were added. The absorbance of the resulting solutions was measured at 700 nm, using distilled water as the blank.

DPPH Radical Scavenging Activity

The DPPH free radical scavenging activity was assessed following the Blois method (Blois, 1958). A 1 mM DPPH solution was used as the free radical source. A stock sample solution with a concentration of 1 mg/mL was prepared, and aliquots were transferred into test tubes to create solutions at final concentrations of 10, 20, and 30 µg/µL. The total volume of each solution was adjusted to 2 mL with ethanol. Subsequently, 0.5 mL of the DPPH stock solution was added to each tube. The mixtures were incubated in the dark at room temperature for 30 minutes, and their absorbance was measured at 517 nm, using ethanol as the blank reference.

ABTS Radical Scavenging Activity

The ABTS radical scavenging activity was evaluated following the method outlined by Re et al. (1999). A 7 mM ABTS solution was prepared, and ABTS radicals were generated by adding a 2.45 mM persulfate solution. The ABTS radical solution was allowed to stabilize, and its absorbance was adjusted to 0.700 ± 0.025 at 734 nm before use. Ethanol extracts at concentrations of 10, 20, and 30 µg/mL were mixed with 0.5 mL of the ABTS radical solution and incubated for 30 minutes. After incubation, the absorbance of each sample was measured at 734 nm, with ethanol used as the blank.

Determination of Total Phenolic Compound Amount

The total phenolic content was determined using gallic acid as the standard. A standard curve was constructed using gallic acid, and a stock solution of the plant extract was prepared. The sample was transferred into a volumetric flask, and the volume was adjusted to 23 mL with distilled water. Subsequently, Folin-Ciocalteu reagent and 2% Na_2CO_3 solution were added to the flask. The mixture was allowed to react at room temperature, and its absorbance was measured at 760 nm, with distilled water

serving as the blank. The gallic acid equivalents (GAE) of the sample were calculated based on the absorbance values using the equation obtained from the standard curve (Kalın et al., 2015).

Determination of Total Flavonoid Content

The total flavonoid content was determined following the method described by Kalın et al. (2015). A 750 µg sample of the extract was measured and transferred into a test tube. The extract was then diluted with an ethanol solution containing CH_3COOK and 10% $Al(NO_3)_3$ solutions. The mixture was vortexed thoroughly and incubated at room temperature. After incubation, the absorbance was measured at 415 nm. Quercetin was used as the standard to calculate the total flavonoid concentration based on the absorbance values.

Effect on Acetylcholinesterase (AChE) Enzyme

AChE catalyzes the hydrolysis of acetylcholine into thiocholine and acetate. During inhibition studies, the produced thiocholine reacts with DTNB (Ellman's reagent), leading to the formation of a yellow-colored compound, 5-thio-2-nitrobenzoic acid. This compound's presence is quantified by measuring its absorbance at 412 nm (Ellman et al., 1961). Absorbance readings for both control and sample cuvettes were taken at 412 nm, specifically at the 5th minute of the reaction. The inhibitory effects of the tested compounds on AChE were evaluated, and the IC_{50} value was determined based on the resulting data.

Effect on Butyrylcholinesterase (BChE) Enzyme

The inhibitory effects of the synthesized compounds on BChE were evaluated using a procedure similar to that employed for AChE. However, instead of acetylthiocholine iodide, which serves as the substrate for AChE, butyrylthiocholine iodide was used as the substrate for BChE. The reaction and analysis steps remained otherwise consistent.

Determination of Phenolic Compounds

The analyses were performed at the Central Research and Application Laboratory of Ağrı İbrahim Çeçen University using a liquid chromatography system (Spark Holland) integrated with a tandem mass spectrometry system (AB SCIEX 4000 QTRAP) (LC-MS/MS). Chromatographic separation was carried out using a C18 column (Inertsil ODS-3V, 250 mm × 4.6 mm, 5 µm). The mobile phases were 0.1% (v/v) formic acid solution (A) and methanol (B). The injection volume was set to 10 µL, with a flow rate of 0.700 mL/min, and the column temperature was maintained at 30°C. Qualitative and quantitative analyses were performed in Multiple Reaction Monitoring (MRM) mode, with electrospray ionization (ESI) used as the ionization method.

Results and Discussion

Alzheimer's disease, one of the illnesses caused by ROS, currently has no definitive cure, and existing treatments focus on slowing the progression of the disease. However, some of the medications used in treatment are associated with side effects. For instance, Tacrine has limited use due to its potential to cause liver damage. In this study, the antioxidant capacity of *Muscari armeniacum*, a plant rich in phenolic compounds, was investigated, and its potential application in Alzheimer's treatment was evaluated.

In the study, the antioxidant activities of *Muscari armeniacum* were evaluated using methods such as iron reduction capacity, CUPRAC, ABTS, and DPPH radical scavenging assays. Additionally, tests involving AChE and BChE enzymes were conducted to determine the types of inhibition based on IC_{50} and K_i values. The results suggest that *Muscari armeniacum* has potential as a candidate for the treatment of diseases linked to cellular damage, such as Alzheimer's.

Important factors, like reduction capacity, should be taken into account when assessing a compound's antioxidant potential, as was underlined in this section. Oxidation is the loss of electrons in chemical reactions, while reduction is the gain of electrons. It was mentioned that while reducible compounds frequently have antioxidant qualities, not all of them are.

To evaluate the antioxidant capacity of *Muscari armeniacum*, CUPRAC and Fe^{3+} reduction capacity methods were utilized. The results revealed that *Muscari armeniacum* exhibited a lower reduction capacity compared to standard antioxidants. In terms of Fe^{3+} reduction capacities, a comparison of absorbance values at 10 µg/mL showed the following order: BHA (1.441) > BHT (1.033) > Trolox (0.751) > Ascorbic acid (0.693) > α-Tocopherol (0.418) > *Muscari armeniacum* (0.108) (Table 1). Higher absorbance values indicate stronger reduction capacity. Iron is a critical element for metabolic processes in living organisms but can cause cellular damage when present in excessive amounts. Iron ions can increase the levels of reactive oxygen species (ROS) and free radicals in living organisms, leading to potential harm (Gulcin, 2020; Topal, 2020).

ABTS and DPPH radical scavenging activities are widely used spectrophotometric methods employed in this study. The DPPH radical, when interacting with an antioxidant compound, transitions from a purple color to a lighter shade, serving as an indicator of antioxidant activity. The ABTS radical, on the other hand, dissolves in both water and organic solvents, allowing measurements to be taken within approximately 30 minutes.

Table 1. Comparison of reducing capacities at 10 µg mL^{-1} concentration

Antioxidants	Fe^{3+} Reduction (700 nm)	CUPRAC Method (450 nm)
BHA	1.441	1.239
BHT	1.033	0.680
α-Tocopherol	0.418	0.169
Trolox	0.751	0.260
Ascorbic Acid	0.693	0.342
Muscari armeniacum	0.108	0.054

BHA: Butyl Hydroxy Anisole, BHT: Butyl Hydroxy Toluene, CUPRAC: CUPric Reducing Antioxidant Capacity

Table 2. Comparison of % removal activities at 10 µg mL^{-1} concentration

Antioxidants	$DPPH^{\cdot}$ Removal	$ABTS^{\cdot+}$ Removal
BHA	69.67	99.41
BHT	18.93	99.53
α-Tocopherol	20.70	67.64
Trolox	61.46	99.41
Ascorbic Acid	34.91	84.99
Muscari armeniacum	4.66	17.82

BHA: Butyl Hydroxy Anisole, BHT: Butyl Hydroxy Toluene

Table 3. The amount of total phenolic and total flavonoid compounds found in *Muscari armeniacum*

	Total Phenolic (µg GAE/mg extract)	R^2	Total Flavonoid (µg QE/mg extract)	R^2
Muscari armeniacum	14.38	0.9991	23.24	0.9963

GAE: Gallic acid equivalent, QE: Quercetin equivalent

Table 4. Comparison of *Muscari armeniacum* for AChE and BChE enzymes

	Muscari armeniacum IC_{50} (µg mL^{-1})	
Cholinesterases	IC_{50}	R^2
AChE	54.14	0.9695
BChE	58.73	0.9609

AChE: Acetylcholinesterase, BChE: Butyrylcholinesterase, IC_{50}: Half maximal inhibitory concentration

Additionally, the ABTS method offers the advantage of functioning effectively across a broad pH range (Muglu et al., 2024). At a concentration of 10 µg/mL, the %ABTS radical scavenging activity of *Muscari armeniacum* and standard antioxidants was ranked as follows: BHT > BHA > Trolox > Ascorbic Acid > α-Tocopherol > *Muscari armeniacum* (Table 2).

Copper (Cu) is an essential metal with vital importance for the human body. It is required for iron absorption, and copper deficiency can lead to iron deficiency anemia. Additionally, a correlation has been identified between copper imbalance and Alzheimer's disease. An increase in circulating free copper molecules can accelerate the progression of the disease. Human serum albumin plays a crucial role in the antioxidant defense system and is effective in regulating free copper levels (Durgun et al., 2024; İnan Ergün & Topal, 2023). Copper has been identified as an element that triggers ROS formation, and studies have shown increased copper levels in Alzheimer's disease (Lowell & Shulman, 2005; Topal et al., 2024). Therefore, in this study, the copper reduction capacity and antioxidant effects of *Muscari armeniacum* were evaluated in relation to findings associated with Alzheimer's disease. In conclusion, the antioxidant capacity and AChE and BChE inhibitory properties of *Muscari armeniacum* suggest its potential as an alternative approach in the treatment of Alzheimer's disease. This study aims to contribute to the development of novel pharmacological strategies for challenging diseases such as Alzheimer's, cancer, and Parkinson's.

In the present study, the %DPPH radical scavenging activity of *Muscari armeniacum* was calculated as 4.66% at a concentration of 10 µg/mL. In a study on the ABTS radical scavenging activity of *Sorbus subfusca* fruit, the IC_{50} values were reported as 36.47 µg/mL for the water extract and 33.00 µg/mL for the ethanol extract (Topal & Kocabaş, 2024). The ABTS radical scavenging activity of *Muscari armeniacum* was found to be lower compared to the standard antioxidants. The total phenolic content of the ethanol extract of *Muscari armeniacum* was determined using gallic acid as the standard phenolic compound. A standard curve was constructed, and the total phenolic content in the ethanol extract of *Muscari armeniacum* was calculated as gallic acid equivalents (GAE), amounting to 14.38 µg GAE/mg extract.

The total flavonoid content of the ethanol extract of *Muscari armeniacum* was determined using quercetin as the standard. Using the equation derived from the standard curve, the total flavonoid content was calculated as quercetin equivalents (QE), amounting to 23.24 µg QE/mg extract. The total flavonoid and phenolic contents in the extracts were calculated using the derived equations, and the results are presented in Table 3.

The effects of the ethanol extract of *Muscari armeniacum* on AChE and BChE enzymes were evaluated under saturated substrate concentrations. A graph illustrating the relationship between enzyme activity percentage and *Muscari armeniacum* extract concentration was plotted, and the IC_{50} value was calculated (Table 4). These findings suggest that *Muscari armeniacum* could serve as an alternative approach in the treatment of neurodegenerative diseases.

The phenolic compounds and their quantities of *Muscari armeniacum* were presented in Table 5. Among the phenolic compounds, *Muscari armeniacum* contains higher amounts of p-Coumaric acid (1853.3 ng/g), Quinic acid (1330.0), 4-Dihydroxybenzoic acid (1296.7 ng/g), and Salicilyc acid (960.3), respectively.

A literature review revealed no other studies on this topic, suggesting that the present study is the first to report on the detailed phenolic compounds in *M. armeniacum*. Due to this, we cannot compare the research. The studies are mostly focused on anthocyanins, homoisoflavonoids, odor-profile, and sugar profile. We could compare it with other plants. In a study conducted by Sarikurkcu et al. (2015), the methanol extract of *Phlomis armeniaca* was found to contain 0.77 mg/g catechin, 11.95 mg/g chlorogenic acid, and 0.85 mg/g rutin.

Table 5. Selected phenolics of *Muscari armeniacum* obtained from LC-MS/MS

Phenolic compounds	Retention time	Concentration (ng/g)
2,5-Dihydroxybenzoic acid	3.9	107.7
4-Dihydroxybenzoic acid	8.73	1296.7
Catechin	9.14	76.8
Chlorogenic acid	11.69	36.1
Epicatechin	12.63	29.8
Gallic acid	12.63	97.7
Hesperidin	13.17	nd
Myricetin	13.18	105.4
Naringenin	13.44	58.2
p-Coumaric acid	13.57	1853.3
Pyrogallol	14.11	54.2
Quercetin	14.65	130.3
Quinic acid	14.78	1330.0
Rosmarinic acid	14.91	60.4
Rutin	15.2	41.0
Salicilyc acid	15.21	960.3
Sinapinic acid	15.87	nd
Syringic acid	16.13	501.3
Vanilic acid	17.34	223.7
Vanilin	17.33	55.5

nd: Not detected

Conclusions

This study provides comprehensive insights into the antioxidant and enzyme inhibitory properties of *Muscari armeniacum*, highlighting its potential as a source of bioactive compounds with therapeutic applications. The ethanol extract of *Muscari armeniacum* demonstrated significant antioxidant activity through various assays, including Fe^{3+}-Fe^{2+} reduction capacity, CUPRAC, DPPH, and ABTS radical scavenging activities. Despite exhibiting lower reduction capacities and radical scavenging activities compared to standard antioxidants such as BHA, BHT, and trolox, the plant's flavonoid and phenolic content (23.24 µg QE/mg and 14.38 µg GAE/mg, respectively) underscores its antioxidant potential. The extract displayed moderate inhibition of AChE and BChE enzymes, with IC_{50} values of 54.14 µg/mL and 58.73 µg/mL, respectively. These findings suggest its relevance in the context of neurodegenerative diseases like Alzheimer's, where enzyme inhibition is a therapeutic target. LC-MS/MS analysis identified several phenolic compounds, including high levels of p-coumaric acid, quinic acid, and 4-dihydroxybenzoic acid, which likely contribute to the plant's bioactivity. The results indicate that *Muscari armeniacum* has potential applications in addressing oxidative stress-related conditions and neurodegenerative diseases. Its moderate antioxidant and enzyme inhibitory properties may make it a candidate for further pharmacological studies. As a plant native to Türkiye and a traditional ornamental species, *Muscari armeniacum* holds both ecological and medicinal value. This study underscores the importance of exploring native plants for developing novel therapeutic strategies. Further research is recommended to explore the mechanisms of action of *Muscari armeniacum*'s bioactive compounds and to evaluate its efficacy in in vivo models for oxidative stress and neurodegenerative diseases.

Declarations

CRediT authorship contribution statement

Fevzi Topal: Data curation; Formal analysis; Investigation; Methodology; Writing - review & editing. *Fırat Yılmaz:* Formal analysis; Writing - original draft. *Meryem Topal:* Formal Analysis; Investigation; Methodology; Writing - review & editing. Ahmed Menevşeoğlu: Conceptualization; Investigation; Resources; Writing - original draft; Writing - review & editing.

Declaration of competing interest

The authors declared that there is no conflict of interest.

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Milk Fatty Acid Composition and Seasonal Effect on Fatty Acid Composition of Jersey Cattle Reared in Eastern Mediterranean Region

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ABSTRACT

In this study, the milk fatty acid profile and seasonal changes of Jersey cattle were investigated. 15 Jersey cattle that had calved for the first time were used in the study. Milk samples were taken twice, in summer and winter. As a result of the analyses, it was determined that the season had a limited effect on the fatty acid profile of milk fat. Only in 3 fatty acids (C21:0, C23:0, C18:1 trans11) seasonal variation was observed ($p<0.05$). Although not statistically significant, the content of most saturated and polyunsaturated fatty acids was lower and the content of most monounsaturated fatty acids was higher in summer than in winter.

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Doğu Akdeniz Bölgesinde Yetiştirilen Jersey Sığırların Süt Yağ Asitleri Kompozisyonu ve Yağ Asitleri Kompozisyonuna Mevsim Etkisi

MAKALE BİLGİSİ

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ÖZ

Bu çalışmada Jersey ırkı sığırların süt yağı asit profili ve mevsimsel değişimi incelenmiştir. Araştırmada ilkine buzağılamış 15 baş Jersey ırkı sığır kullanılmıştır. Süt örnekleri yaz ve kış mevsimi olmak üzere iki defa alınmıştır. Yapılan analizler neticesinde mevsimin süt yağının yağ asitleri profili üzerinde sınırlı bir etkisi olduğunu tespit edilmiştir. Sadece 3 yağ asidinde (C21:0, C23:0, C18:1 trans11) mevsimsel değişkenlik gözlemlenmiştir ($p<0,05$). İstatistiksel olarak önemli çıkmasa da yaz mevsiminde çoğu doymuş ve çoklu doymamış yağ asitlerinin içeriğinin daha düşük ve çoğu tekli doymamış yağ asitleri içeriği kış mevsimine göre daha yüksek olduğu görülmüştür.

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Giriş

Son yıllarda hayvansal gıda ürünlerinin besin değeri ve insan sağlığına faydaları konusuna olan ilgi giderek artmaktadır. Önemli bir diyet bileşeni olan sığır sütünün insan sağlığı üzerindeki etkilerini değerlendirmek için çok sayıda araştırma yapılmıştır. Yağ, sığır sütündeki en önemli bileşenlerden biri olup içeriği sığır ırkına, beslemeye, bireysel özelliklere, laktasyon dönemine ve mevsime bağlı olarak %2,8 ile %8,1 arasında değişmektedir. Süt yağları basit lipitler, bileşik lipitler, serbest (esterleşmemiş) yağ asitleri, lipit türevleri (steroller ve karotenoidler) ve yağda çözünen vitaminleri içerir. Süt yağı, gliserolün yağ asitleriyle bağlanmasıyla meme bezi hücrelerinde lipit kürecikleri şeklinde sentezlenir. Lipitler sindirim sisteminde hidrolize uğramadan doğrudan emilebilirler, bu da süt yağının çok yüksek sindirilebilirliğine (%97-99) katkıda bulunur (Micinski ve ark., 2012).

Sığır sütü yağı 400'den fazla yağ asidi içerir ancak %1'in üzerindeki konsantrasyonlarda yalnızca 15 veya 16 farklı yağ asidi bulunur; bu esas olarak geviş getiren hayvanın ırkına, rasyonuna, laktasyon aşamasına ve mevsime bağlıdır (Jensen, 2002; Schroeder & Vetter, 2013; Shingfield ve ark., 2013; Hanuš ve ark., 2018). Yağ asitleri çift bağ sayısına göre doymuş yağ asitleri (DYA), tekli doymamış (TDYA) veya çoklu doymamış yağ asitleri (ÇDYA) olarak tanımlanabilir (Taylor & MacGibbon, 2011).

Süt yağı %5 oranında doymuş yağ içermesine rağmen kronik hastalıklar için olumlu etkinlikleri olan konjuge linoleik asit, sifingomiyelin, bütirik asit, miristik asit gibi özel bileşenler içerdiği için sağlık açısından önemlidir (Ünal & Besler, 2012).

Süt ürünlerinin (tereyağı hariç) ABD diyetindeki doymuş yağ alımının %24'üne ve Avrupa ülkelerinde %25-30'una katkıda bulunduğu ifade edilmektedir (Liang ve ark., 2018). Metabolik sendrom ve kardiyovasküler hastalık (KVH) riskini azaltmak için diyetle alınan doymuş yağ asitlerinin (DYA) en aza indirilmesi gerektiği dogması, onlarca yıldır beslenme kılavuzlarına hakim olmuştur ve süt yağındaki yüksek DYA içeriği (toplam DYA'nın yaklaşık üçte ikisi) şu anda süt ürünleri tüketimini bu patolojilerin artan sıklığıyla ilişkilendirmek için bir argüman olarak kullanılmaktadır. Ancak, son bilimsel çalışmalar bu önerilerin sağlıklı bir popülasyonda sürdürülmesini haklı çıkarmamaktadır (Astrup ve ark., 2016; Lovegrove & Givens, 2016; Guo ve ark., 2017). İlk olarak, güncel araştırmalar süt yağı alımının biyobelirteçleri ile diyabet veya kardiyovasküler hastalık riski arasında bir ilişki olduğunu desteklememektedir (Kleber ve ark., 2016; Yakoob ve ark., 2016; Liang ve ark., 2018). Dahası, gözlemsel kanıtlar yüksek yağlı süt ürünlerinin metabolik sendroma veya kardiyovasküler riske katkıda bulunduğu hipotezini desteklememekte ve hatta tipik diyet düzenleri içinde yağlı süt tüketiminin bu riskle ters orantılı olduğunu göstermektedir (Kratz ve ark., 2013; Alexander ve ark., 2016; Thorning ve ark., 2017).

Süt yağı, insan sağlığı üzerinde potansiyel faydaları olan belirli biyoaktif yağ asitlerinin doğal ve neredeyse tek kaynağıdır. Bunlardan bazıları başka yerlerde diyetlerimizde önemli miktarlarda bulunmaz ve az yağlı veya yağsız süt ürünlerinin tüketimi bunların alımını sınırlar. Örneğin, süt yağı insan diyetinde neredeyse bütirik asit (4:0), konjuge linoleik asit (CLA) ve dallı zincirli yağ asitlerinin tek kaynağıdır. Bu yağ asitleri süt yağında yalnızca küçük bir yüzdeyi oluşturmasına rağmen, küçük miktarlar tek başına biyolojik olarak önemlidirler (Kratz ve ark., 2013).

Talpur ve ark., (2008), geviş getiren hayvanların yıl boyunca süt yağ asit profilindeki değişimleri incelemiş ve genel olarak doymuş yağ asitlerinin (DYA) kışın daha yüksek ve yaz aylarında düşük seviyelerde olduğunu belirtmişlerdir. Yaz aylarında süt yağında kışa göre %5-10 daha az doymuş yağ asidi mevcut olduğunu bildirmişlerdir. Genel olarak sütteki kısa zincirli yağ asitleri konsantrasyonunun (<14:0) kışın en yüksek ve yazın en düşük olduğunu, C16:0 içeriğinin diğer tüm mevsimlere kıyasla yaz döneminde önemli ölçüde yüksek olduğunu bildirmişlerdir.

Büyükbeşe (2014), yaptığı çalışmada yağ asidi kompozisyonundaki mevsimsel değişimlerin süt yağının yapısal özelliklerini etkilediğini bildirmiştir. Farklı mevsimlerde üretilen sütlerin yağ asit kompozisyonları incelendiğinde süt yağında bulunan başlıca yağ asitleri misirtik (C14:0), palmitik (C:16), stearik (C18:0) ve oleik (C18:0) asit olduğu bildirilmiştir.

Yapılan çalışmalarda yaz aylarında kısa ve orta zincirli yağ asitlerinin oranı düşerken, uzun zincirli yağ asitlerinin oranının arttığı bildirilmiştir (Thomas & Rowney, 1996; Alonso ve ark., 1999; Månsson, 2008).

Shi ve ark., (2001), oleik asit (C18:1) ve linoleik asit (C18:2) miktarlarının yaz aylarında elde edilen süt yağında diğer mevsimlere göre daha yüksek olduğunu, kış aylarında elde edilen süt yağının palmitik asit (C16:0) miktarının genel olarak arttığını bildirmişlerdir.

Bu çalışmada, ilk laktasyonunda olan Jersey ırkı ineklerden, yaz ve kış aylarında elde edilen süt numunelerinin yağ asidi kompozisyonları ve bu yağ asitleri kompozisyonunun mevsimsel değişiminin belirlenmesi amaçlanmıştır.

Materyal ve Yöntem

Materyal

Çalışmada hayvan materyali olarak Adana ilinde özel bir işletmede yetiştirilen birinci laktasyondaki 15 baş Jersey ırkı hayvan kullanılmıştır.

Süt Örneklerinin Alınması

Süt örnekleri yaz mevsimi (Temmuz) ve kış mevsimi (Ocak) olmak üzere iki ayrı dönemde, sabah sağımında sağım sistemine takılan örnek toplama kabı yardımıyla homojen şekilde alınmıştır. Örnekler 100'er ml'lik steril plastik tüplere aktarılmıştır. Alınan süt örnekleri soğuk zincirde hızlıca laboratuvara ulaştırılmıştır.

Lipid Analizi

Süt örnekleri Bligh ve Dyer (1959)'in geliştirdiği yönteme göre lipid analizine tabii tutulmuştur. Yaklaşık 10 g süt örneği üzerine 100 ml metanol/kloroform (1/2) karışımı eklendikten sonra yaklaşık 1 dakika Ultra-turaks (T 25 basic IKA-WERE) ile homojenize edilmiştir. Elde edilen karışımlar 105 ºC'de 2 saat etüvde tutulup darası alınmış olan balon jojelere üzerine 20 ml %0,4'lük $CaCl_2$

solüsyonundan ilave edilerek filtre kağıdı ile süzdürülmüştür. Balon jojeler hava girmeyecek şekilde parafilmle kapatılıp 24 saat karanlık bir ortamda bekletilmiştir. Bekleme işleminden sonra ayırma hunisi yardımıyla kloroform-yağ karışımının (alt faz) balona alınmıştır. Balon içerisindeki kloroform-lipit kısmından kloroform 60ºC'de su banyosunda rotary evaparatör kullanılarak uçurma işlemi gerçekleştirilmiştir. Sonrasında balonlar 65ºC'de 30 dakika tutularak içerisindeki kloroformun tümünün uçması sağlanmıştır. Balonlar desikatörde oda sıcaklığına kadar soğutulmuştur. Balonlar 0,1 mg duyarlı hassas terazide tartılmıştır.

Yağ Asitleri Analizi

Eksrakte edilmiş lipitten, yağ asidi metil esterleri Ichibara ve ark., (1996)'nın geliştirdiği yönteme göre elde edilmiştir. 4ml 2M'lık KOH ve 2 ml n-heptan 25 mg eksrakte edilmiş yağ örneği üzerine eklenmiştir. Sonrasında vortekste oda sıcaklığında 2 dk karıştırılmış ve 4000 rpm'de 10 dk süre ile santrifüj edilmiştir. Daha sonra heptan tabakası analiz için GC'ye alınmıştır.

Yağ asitleri kompozisyonun belirlenmesi için alev iyonizasyon dedektörlü (FID) ve 30m × 0,32mm ID × 0,25µm film kalınlığında SGE kolonlu otomatik örneklemeli (Perkin Emler, USA) GC (Gaz kromatografik) kullanılmıştır. Enjektör ve detektör sıcaklığı ise sırası ile önce 220°C sonra 280°C' ye ayarlanmıştır. Bu sırada fırın sıcaklığı 5 dakika boyunca 140°C'de tutulmuştur. Daha sonra her dakika 4°C arttırılarak 200°C'ye, her dakika 1°C arttırılarak 200°C'den 220'ye çıkarılmıştır. Taşıyıcı gazın kontrolü 16 ps'de olması sağlanmıştır. Split uygulaması ise 1:50 oranında uygulanmıştır. Standart 37 bileşenden oluşan FAME karışımının gelme zamanlarına bağlı olarak karşılaştırılmasıyla yağ asitleri belirlenmiştir.

İstatistiksel Analizler

Çalışmada elde edilen veriler SPSS 26 programında Tek Yönlü Varyans Analizi yöntemi ile analiz edilmişlerdir.

Çalışmada kullanılan matematik model, eşitlikteki gibidir.

$$Y_{ij}= \alpha+\mu_i+e_{ij}$$

Y_{ij} : i. mevsimin j. süt örneğindeki yağ asit kompozisyonu
α : i. mevsime ait etki payı
μ_i : popülasyon ortalaması
e_{ij} : deneme hatası

Bulgular ve Tartışma

Çizelge 1'de araştırmaya dahil olan Jersey ineklerinin Doymuş Yağ Asit kompozisyonu ve bu değerlere ait ortalamalar, minimum ve maksimum değerler belirtilmiştir.

Çizelge 1 incelendiğinde C21:0 ve C23:0 yağ asitlerinin yaz/kış ortalamaları arasında istatistiksel olarak anlamlı bir fark olduğu tespit edilmiş ($p<0,05$) ancak diğer yağ asitlerinde herhangi bir anlamlı fark bulunamamıştır.

Mevsim, süt yağının yağ asitleri bileşimindeki varyasyonun bir kaynağı olarak kabul edilebilir (Jensen, 2002; Frelich ve ark., 2012; Adler ve ark., 2013; Adamska ve ark., 2014). Mevsimin DYA oranı üzerindeki olumlu etkisi çeşitli araştırıcılar tarafından ifade edilmiştir (Månsson ve ark., 2003; Collomb ve ark., 2008; Özcan ve ark., 2015).

Frelich ve ark., (2012), kapalı alanda tutulan sürülerde Kış ayına kıyasla Yaz aylarında daha düşük kısa zincirli doymuş yağ asitleri (C4:0/C10:0) ve C12:0 içeriği tanımlamıştır ($P<0,05$). Yine Gottardo ve ark., (2017), doymuş yağ asitlerinin oranının yaz mevsiminde (Haziran-Eylül) azaldığını bildirmişlerdir. Talpur ve ark., (2008)'da yaz aylarında süt yağında kışa kıyasla %5-10 daha az doymuş yağ asidi varlığını tespit etmişlerdir.

Wang ve ark., (2021), çeşitli türlerin sütlerine ait yağ asit profillerinin belirlenmesi için yürüttükleri çalışmalarında Jersey (n=32) ırkı sığırların C21:0 yağ asit ortalamasını (0,05±0,01) ve C23:00 yağ asit ortalamasını (0,06±0.,02) olarak çalışmamıza benzer şekilde tespit etmişlerdir.

Yine yapılan bir araştırmada çalışmamıza benzer şekilde yaz mevsiminde doymuş ve çoklu doymamış yağ asitleri içeriği kış mevsimine göre daha düşük tespit edilmiştir (Hanuš ve ark., 2016).

Çizelge 2'de araştırmaya dahil olan Jersey ineklerinin Tekli Doymamış Yağ Asitleri kompozisyonu ve bu değerlere ait ortalamalar, minimum ve maksimum değerler belirtilmiştir.

Çizelge 2 incelendiğinde sadece C18:1 trans11 yağ asidinin mevsimden etkilendiği ve yaz aylarında bir artış gösterdiği tespit edilmiştir ($P<0,05$). Yine çizelgeye bakıldığında genel olarak yaz aylarında yağ asitlerinde istatistiksel olarak önemli çıkmasa da bir artışın varlığından söz edilebilir. Yener ve ark., (2021)'da doymamış yağ asitleri miktarını yaz aylarında yüksek olarak tespit etmişlerdir.

Uzun ve ark., (2023), yaptıkları çalışmalarında C14:1 (1,76±0,31); C15:1 (1,75±0,87) ve C17:1 (1,60±0,71) yağ asidini çalışmamızda elde edilen orandan yüksek olarak, C16:1 (1,30±0,43) yağ asidini ise düşük olarak tespit etmişlerdir. Ancak bu çalışmada kullanılan sığır ırkı verilmediğinden ırk farklılığından da bu sonuçların olabileceği ifade edilebilir.

Çizelge 3'te araştırmaya dahil olan Jersey ineklerinin Çoklu Doymamış Yağ Asitleri kompozisyonu ve bu değerlere ait ortalamalar, minimum ve maksimum değerler belirtilmiştir.

Antikanser ve sağlık açısından diğer olumlu özellikleri nedeniyle konjuge linoleik aside (CLA) (McGuire & McGuire, 2000; Collomb ve ark. 2008) ve koroner kalp hastalığına olan yararlı etkisi nedeniyle linolenik aside (C18:3 n-3) özel bir önem verilmektedir (De Caterina & Zampolli, 2001; Kristensen ve ark., 2001).

Çizelge 3 incelendiğinde, CLA ve Linoleik asit düzeyleri yapılan diğer bazı çalışmalarla (Hanus v ark., 2016; Büyükoğlu ve ark., 2017) benzer olmalarına karşın mevsimden etkilenmemiştir ($P>0,05$).

Yine çalışmamıza benzer olarak Frelich ve ark., (2012) ve Özcan ve ark., (2015) mevsimin C18:3n3, C18:2n6 içeriği üzerinde bir etkisi olmadığını ifade etmişlerdir.

Ayrıca Lindmark-Mansson ve ark., (2003) ile Frelich ve ark., (2012) tarafından da mevsimin ÇDYA üzerine anlamlı bir etkide bulunmadığını ifade etmişlerdir.

Buna karşılık, Collomb ve ark., (2008) ve Adler ve ark., (2013) bu iki yağ asit içeriği üzerinde açık hava/yaz mevsiminin olumlu bir etkisi olduğunu gözlemlemişlerdir ($P<0,05$).

Çizelge 1. Yaz ve Kış Aylarında Doymuş Yağ Asitleri Profili (%).
Table 1. Saturated Fatty Acids Profile in Summer and Winter (%).

Yağ Asitleri	Mevsim	N	Min	Max	x̄ ± Sx	F	Sig.
C4:0	Yaz	15	3,15	3,33	3,25 ±0,017	0,399	0,533
	Kış	15	3,16	3,34	3,27±0,013		
C6:0	Yaz	15	2,11	2,53	2,34±0,032	0,004	0,949
	Kış	15	2,17	2,69	2,34±0,040		
C8:0	Yaz	15	0,95	1,08	1,00±0,011	1,469	0,236
	Kış	15	0,96	1,07	1,02±0,009		
C10:0	Yaz	15	2,10	2,16	2,13±0,005	2,222	0,147
	Kış	15	2,10	2,22	2,14±0,007		
C11:0	Yaz	15	0,29	0,38	0,33±0,007	0,155	0,697
	Kış	15	0,29	0,41	0,34±0,009		
C12:0	Yaz	15	2,94	3,50	3,20±0,046	0,996	0,327
	Kış	15	2,95	3,62	3,27±0,050		
C13:0	Yaz	15	0,10	0,25	0,16±0,013	0,228	0,636
	Kış	15	0,10	0,29	0,17±0,016		
C14:0	Yaz	15	12,98	14,76	13,87±0,17	0,122	0,730
	Kış	15	13,19	14,18	13,80±0,09		
C15:0	Yaz	15	1,85	2,00	1,92±0,014	0,357	0,555
	Kış	15	1,86	2,01	1,93±0,012		
C16:0	Yaz	15	32,00	34,35	33,23±0,22	0,134	0,717
	Kış	15	32,10	34,61	33,34±0,18		
C17:0	Yaz	15	0,80	0,85	0,82±0,004	2,000	0,168
	Kış	15	0,81	0,86	0,83±0,003		
C18:0	Yaz	15	4,81	5,09	4,96±0,022	1,441	0,240
	Kış	15	4,84	5,34	5,02±0,038		
C20:0	Yaz	15	0,17	0,21	0,18±0,003	0,000	1,000
	Kış	15	0,17	0,21	0,18±0,003		
C21:0	Yaz	15	0,60	0,63	0,61±0,002	9,645	0,004*
	Kış	15	0,60	0,65	0,62±0,003		
C23:0	Yaz	15	0,04	0,09	0,06±0,003	5,762	0,023*
	Kış	15	0,05	0,09	0,07±0,002		
C24:0	Yaz	15	0,04	0,08	0,06±0,004	0,019	0,891
	Kış	15	0,05	0,08	0,05±0,002		

*(p<0,05)

Çizelge 2. Yaz ve Kış Aylarında Tekli Doymamış Yağ Asitleri Profili (%).
Table 2. Monounsaturated Fatty Acids Profile in Summer and Winter (%).

Yağ Asitleri	Mevsim	N	Min	Max	x̄ ± Sx	F	Sig.
C14:1	Yaz	15	1,16	1,27	1,23±0,008	1,344	0,256
	Kış	15	1,15	1,26	1,22±0,010		
C15:1	Yaz	15	0,15	0,18	0,16±0,002	1,691	0,204
	Kış	15	0,15	0,19	0,17±0,003		
C16:1	Yaz	15	1,71	1,98	1,83±0,020	0,036	0,850
	Kış	15	1,76	1,93	1,82±0,013		
C17:1	Yaz	15	0,28	0,35	0,31±0,006	0,781	0,384
	Kış	15	0,29	0,35	0,32±0,004		
C18:1 trans6	Yaz	15	0,30	0,39	0,36±0,006	3,080	0,090
	Kış	15	0,33	0,41	0,37±0,005		
C18:1 trans9	Yaz	15	0,19	0,26	0,22±0,006	0,834	0,369
	Kış	15	0,19	0,26	0,21±0,006		
C18:1 trans11	Yaz	15	0,31	0,42	0,36±0,007	4,469	0,044
	Kış	15	0,32	0,38	0,34±0,004		
C18:1 n9	Yaz	15	18,6	20,8	19,54±0,188	1,652	0,209
	Kış	15	18,4	20,3	19,24±0,145		
C24:1 n9	Yaz	15	0,94	1,48	1,23±0,047	0,054	0,818
	Kış	15	0,98	1,47	1,22±0,031		

*(p<0.05)

Çizelge 3. Yaz ve Kış Aylarında Çoklu Doymamış Yağ Asitleri Profili (%).
Table 3. Polyunsaturated Fatty Acids Profile in Summer and Winter (%).

Yağ Asitleri	Mevsim	N	Min	Max	x̄ ± Sx	F	Sig.
C18:2n6 Linoleic Asit	Yaz	15	2,22	2,45	2,35±0,035	0,094	0,761
	Kış	15	2,30	2,55	2.44±0,010		
C18:2 (9,11 – CLA) Konjuge Linoleik Asit	Yaz	15	0,72	0,79	0,74±0,004	0,221	0,682
	Kış	15	0,60	0,65	0,62±0,006		
C18:3n3	Yaz	15	0,36	0,54	0,45±0,015	0,085	0,772
	Kış	15	0,38	0,51	0,44±0,012		
C20:2	Yaz	15	0,11	0,17	0,13±0,005	0,117	0,735
	Kış	15	0,10	0,18	0,13±0,005		
C20:5n3	Yaz	15	0,36	0,42	0,39±0,004	0,627	0,435
	Kış	15	0,36	0,43	0,39±0,005		
C22:6n3	Yaz	15	0,14	0,23	0,18±0,009	0,016	0,902
	Kış	15	0,15	0,22	0,18±0,005		

Sonuç

Bu çalışma mevsimin süt yağının yağ asitleri profili üzerinde yalnızca küçük bir etkiye sahip olduğunu göstermiştir. Sadece 3 yağ asidinde mevsimsel değişkenlik gözlemlenmiştir. İstatistiksel olarak önemli çıkmasa da yaz mevsiminde çoğu doymuş ve çoklu doymamış yağ asitlerinin içeriği daha düşük ve çoğu tekli doymamış yağ asitleri içeriği kış mevsimine göre daha yüksek olarak tespit edilmiştir.

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Sociological Dimension of Traditional Foods

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ABSTRACT

While local traditional dishes reflect the historical, geographical and cultural characteristics of regions, the eating habits of individuals provide clues to the social and economic structure. Today, traditional food production is suffering from a serious loss of competitiveness in the face of global industrial food production and distribution. Farmers who produce traditional agricultural products are threatened with extinction. This situation means both the loss of traditional products and the disappearance of an important part of our food and drink culture. The European Union (EU) has launched a major project called TRUEFOOD to prevent this loss and to assess and resolve the problem in all its dimensions. Through this project, the EU aims to ensure the protection of traditional foods under the conditions of global competition and to harmonize production processes with the food safety standards required by the times. In Turkey, the Traditional Foods Symposium (GGS) series, which was initiated in parallel with this process and has been organized for about 20 years, is trying to record our traditional foods. In addition, various institutions are trying to protect "traditional foods" with Geographical Indication (GI) registrations, as in the EU. Many of the papers presented in the GGS series show that traditional foods are not only raw materials and production technologies, but also an expression of social identity, a religious ritual, a phenomenon that promotes solidarity, and a whole that reflects the memories of individuals. In the future symposiums of the series, it is thought that the establishment of a tradition in which the histories and sociological dimensions of our "traditional foods" are studied together in their recording will be of great benefit in terms of the continuity of our culture.

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Geleneksel Gıdaların Sosyolojik Boyutu

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ÖZ

Yerel geleneksel yemekler bölgelerin tarihsel, coğrafi ve kültürel özelliklerini yansıtırken, bireylerin yeme alışkanlıkları ise sosyal ve ekonomik yapıya dair ipuçları sunar. Günümüzde, küresel endüstriyel gıda üretimi ve dağıtımı karşısında geleneksel gıda üretimi ciddi bir rekabet gücü kaybı yaşamaktadır. Geleneksel tarımsal ürünlerin üreticisi olan çiftçiler, yok olma tehlikesiyle karşı karşıyadır. Bu durum hem geleneksel ürünlerin kaybı hem de yeme-içme kültürümüzün önemli bir kısmının yok olması anlamına gelmektedir. Avrupa Birliği (AB) bu kaybın önlenmesi ve sorunun tüm boyutları ile değerlendirilip çözümü için kısa adı TRUEFOOD olan büyük bir proje yürütmüştür. Bu proje kapsamında AB, geleneksel gıdaların küresel rekabet koşullarında korunmasını sağlarken, üretim süreçlerinin çağın gerektirdiği gıda güvenliği standartlarına uyumlu hâle getirilmesini hedeflemiştir. Türkiye'de ise bu sürece parelel olarak başlatılan ve yaklaşık 20 yıldır düzenlenen Geleneksel Gıdalar Sempozyumu (GGS) serisi ile geleneksel gıdalarımız kayıt altına alınmaya çalışılmaktadır. Ayrıca çeşitli kurumlar AB'de olduğu gibi Coğrafi İşaret (Cİ) tescilleri ile "geleneksel gıdaları" korumaya çalışmaktadır. GGS serisinde sunulan birçok makalede, geleneksel gıdaların sadece ham madde ve üretim teknolojilerinden ibaret olmadığı; bununla birlikte toplumsal kimlik ifadesi, dini ritüel, dayanışmayı teşvik eden bir olgu ve bireylerin hatıralarını yansıtan bir bütün olduğu görülmektedir. Serinin gelecek sempozyumlarında ise "geleneksel gıdalarımızın" kayıt altına alınmasında onların hikâyelerinin ve sosyolojik boyutlarının birlikte inceleneceği bir gelenek oluşturulmasının kültürümüzün devamlılığı açısından büyük yararlar sağlayacağı düşünülmektedir.

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Giriş

Kültür, toplumları geçmişten bugüne taşıyan temel unsurları içerir ve bireylerin toplumla etkileşime geçtikçe şekillenen kimliklerinin temellerini atar. Kültür, soyut kavramlar (din, inançlar, değerler, tutumlar) ve somut yapılar (kurumlar, festivaller, gelenekler) aracılığıyla toplumları yapılandırır. Bu unsurlar, bireylerin toplum içindeki davranışlarını şekillendirirken toplumsal yapıları da belirler. Bireylerin kültürel değerleri öğrendiği süreç, toplumsallaşma olarak adlandırılır. Bu süreç, bireylerin toplumsal kimlik edinmelerini ve kültürel normlara uyum sağlamalarını mümkün kılar (Sağır, 2012). Bu noktada kültürün, bireylerin toplumla olan ilişkisini biçimlendirdiği söylenebilir. Bu etkileşimin en temel ve en görünür örneklerinden biri de yemek kültürüdür.

Yemek, yalnızca fizyolojik bir gereklilik olarak kabul edilmekle kalmaz, aynı zamanda toplumsal ve kültürel anlamlar taşır. Toplumlar, yemek aracılığıyla sadece beslenmez; aynı zamanda kültürel kimliklerini, değerlerini ve toplumsal ilişkilerini de şekillendirirler. Beslenme, vücuda gerekli besinlerin alınmasıyla ilişkilidir ancak bu süreç; besinlerin üretimi, dağıtımı, hazırlanması ve tüketilmesi gibi çok sayıda toplumsal süreci kapsar. Bu durum, beslenmenin yalnızca bireysel bir eylem olmadığını; ekonomi, sağlık, siyaset, psikoloji ve sosyoloji gibi bilimlerle bağlantılı bir konu olduğunu gösterir (Yıldızlar, 2022).

Beslenme alışkanlıkları, sadece bireysel tercihlerle değil, aynı zamanda coğrafi, kültürel ve toplumsal faktörlerle şekillenen dinamik bir süreçtir. Bu süreç, toplumların yaşam tarzlarını, ekonomik yapısını ve sosyal ilişkilerini derinden etkileyen önemli bir boyut taşır. Gıda sistemi, bireylerin kendilerini yeniden üretebilmeleri için doğayla ve diğer insanlarla kurdukları ilişkilerle şekillenen karmaşık bir olgudur (Koç, 2020).

Gıda, insanların hayatta kalabilmeleri için temel bir gereksinimdir. Ancak yalnızca bu gereksinimi karşılamakla kalmaz. Aynı zamanda bu gıdayı temin eden ve onu koruyan bir yardıma da ihtiyaç vardır. İnsanlar, hayatta kalabilmek için beslenmeye bağımlıdırlar ancak bunun ötesinde toplumsal ilişkilerin desteğine ve korunmasına muhtaçtırlar. Bu nedenle gıda, hayati bir ihtiyaç olarak ilim ve sanatlardan önce gelir. Eğitim ve kültürel faaliyetlere zaman ayırabilmek için önce temel gereksinimleri karşılamak gereklidir (Zorlu, 2020).

Her birey gıda temini, güvenlik ve savunma ihtiyaçlarını karşılamak için başkalarına ve toplumların iş birliğine ihtiyaç duyar. Bu, toplumsal yapının temel bir özelliğidir ve bireyler arasındaki dayanışmayı teşvik eder. Bu bağlamda, iş birliği, bireysel çıkarların ötesine geçerek ortak bir amaca ulaşmak için gereklidir (Yavuz, 2014).

İbn Haldun *Mukaddime* adlı eserinde yeme-içme alışkanlıklarının yalnızca fizyolojik bir ihtiyaç olmadığını, aynı zamanda toplumsal yapıyı ve bireylerin sağlık durumlarını etkileyen bir olgu olduğunu derinlemesine tartışır. İbn Haldun'a göre, beslenme sadece vücudun enerji ihtiyacını karşılamakla kalmaz, aynı zamanda toplumsal ve kültürel yapıyı da şekillendirir. Hadari (Kent) toplumlarında, besin bolluğu ve fazla yemek yeme alışkanlıkları, sağlığı olumsuz yönde etkileyerek toplumun zayıflamasına yol açar. Hadari toplumları refah içinde yaşarlar. Ancak buna rağmen hareketsizlik ve aşırı beslenme gibi alışkanlıklar, fiziksel ve toplumsal hastalıkların yayılmasına neden olur. Bu durum, sadece bireylerin beden sağlığını değil, aynı zamanda toplumların genel dinamiklerini, bireyler arasındaki ilişkileri ve hatta toplumsal yapıyı da olumsuz şekilde etkiler. İbn Haldun, bu tür toplumların beslenme alışkanlıklarının, toplumların kültürel ve ekonomik yapısıyla bağlantılı olarak şekillendiğini ileri sürer. Hadari toplumlarında, insanlar genellikle rahata alışmış, fazla yemek yiyerek ve hareketsiz kalarak yaşamlarını sürdürürler. Bu durum, fizyolojik düzeyde aşırı kilo alımı ve bununla bağlantılı hastalıkların artmasına, sosyal düzeyde ise toplumda genel bir tembellik ve uyumsuzluk durumuna yol açar. Besin bolluğuna rağmen, bireyler genellikle sağlıklı ve dengeli bir yaşam sürmekte zorlanırlar. Bu durum, hadari toplumlarının doğasında var olan zenginlikten çok, bu zenginliğin nasıl kullanıldığıyla ilgilidir. Yani, fazla yemek yemenin, sadece bireysel sağlığı değil, aynı zamanda toplumsal sağlığı ve dengeyi de bozduğuna dikkat çeker. Buna karşılık, bedevi toplumları daha sade bir yaşam tarzı sürdürür. İbn Haldun, bedevi toplumlarının beslenme alışkanlıklarının, toplumun genel sağlığıyla doğrudan bağlantılı olduğunu belirtir. Bedevi yaşam tarzında, yemek alışkanlıkları daha ölçülüdür ve bireyler açlık durumuna daha alışkındırlar. Bu durum, sağlık açısından olumlu etkiler yaratır. Az yemek yemek, vücudu dinç tutar ve sindirim sisteminin daha verimli çalışmasını sağlar. İbn Haldun bedevi yaşam tarzının yalnızca sade beslenmeye dayalı olmadığını, aynı zamanda bu yaşam tarzının temiz hava almak, doğal çevre ile uyumlu yaşamak ve hareketli bir yaşam sürdürmek gibi unsurlarla da bağlantılı olduğunu vurgular. Bu unsurlar, bedevi toplumlarının sadece fiziksel sağlıklarını değil, ruh hâllerini de iyileştirir. Bedevi toplumlarındaki bu sade yaşam tarzı, bireylerin genel yaşam kalitesini artırırken, aynı zamanda toplumsal uyum ve sağlığı da korur. Temiz hava, doğayla iç içe olmak ve hareketli yaşam, bireylerin fiziksel sağlığını güçlendirir. İbn Haldun, bedevi yaşam tarzının, fiziksel ve psikolojik sağlığı dengede tutmanın yanı sıra toplumdaki bireyler arasında daha sağlam bir bağ oluşturduğuna inanır. Bedevi toplumlarında, bireyler genellikle sağlıklı bir şekilde yaşarlar ve bu sağlık, onların ruh hâllerini de iyileştirir. Bu durum, bedevi toplumlarının uzun vadede daha dayanıklı ve sağlıklı olmalarını sağlar. (İbn Haldun, 2009).

Vücuda alınan gıda ile fiziki ve zihinsel yapı arasında güçlü bir bağ vardır. Bu bağ, farklı toplumlar arasındaki beslenme düzeni farklarını da yansıtır. Haldun'a göre, beslenme tarzı sadece biyolojik değil, aynı zamanda toplumsal ve ahlaki bir rol oynar. Beslenme alışkanlıkları, bireylerin karakterlerini ve toplumların sosyal yapısını belirleyen unsurlar arasındadır (Şahin ve Belge, 2016).

Fatih Sultan Mehmet'in hafif ve az yemek yeme tavsiyesi, yemek alışkanlıklarının sağlık ve performans üzerindeki etkisini vurgularken, toplumsal yapıların yemek pratiklerine olan yansımalarını da göstermektedir. Kırsal kesimde yemeklerin hızlı ve pratik şekilde yenmesi, işlere çabucak dönme gerekliliğiyle ilişkilidir. Bu durum, "Adam olacak kişi sofrada yemek yiyişinden belli olur." gibi söylemlerle toplumsal düzenin bir yansıması hâline gelir. Kentlerde ise yemeklerin yavaş yenmesi ve sağlığa verilen önem, toplumsal farkındalık düzeyinin yüksekliğiyle

açıklanabilir. İbn Haldun'un bedevi (göçebe) ve hadari (yerleşik) toplumları arasındaki farkları gibi, yemek alışkanlıkları da toplumların ekonomik ve kültürel yapılarının bir göstergesi olarak değerlendirilir. Bu nedenle, yemek yalnızca karın doyurma değil, aynı zamanda toplumsal yapıyı anlamlandırmanın bir aracı olarak öne çıkar (Ersoy ve Özgen, 2009).

Geleneksel Gıdaların Sosyal Boyutu

Mevzuatımızda gıda, "doğrudan insan tüketimine sunulmayan canlı hayvanlar, yem, hasat edilmemiş bitkiler, tedavi amaçlı kullanılan tıbbi ürünler, kozmetikler, tütün ve tütün mamulleri, narkotik veya psikotropik maddeler ile kalıntı ve bulaşanlar hariç, insanlar tarafından yenilen, içilen veya yenilmesi, içilmesi beklenen işlenmiş, kısmen işlenmiş veya işlenmemiş her türlü madde veya ürün, içki, sakız ile gıdanın üretimi, hazırlanması veya muameleye tâbi tutulması sırasında kullanılan su veya herhangi bir maddeyi" ifade eder (Anonim, 2010). Görüldüğü üzere, AB mevzuatından esinlenerek yapılan bu genel tanımda sosyolojik bir ifade yer almamaktadır. Ancak 2000'li yılların başında, Avrupa Birliği, geleneksel gıdaların genel gıda güvenliği yönergelerinin etkisiyle kaybolma tehlikesi yaşadığını fark etmiş ve konuyu daha derinden incelemeye karar vermiştir. Bu doğrultuda başlatılan TRUEFOOD projesi Avrupa tüketicisi için geleneksel gıdanın ne anlama geldiğini belirlemek amacıyla 6 ülkeyi içine alan kapsamlı bir çalışma yapmış ve her ülkeden 800'er kişi ile anketler gerçekleştirmiştir. Bu çalışmada; Fransa, İtalya, İspanya, Belçika, Polonya ve Norveç'te geleneksel gıda algısı bakımından büyük farklılıklar görülmüş, ancak her bir ülkede çok kuvvetli bir geleneksel gıda algısına rastlanmıştır. Çalışmaya göre, tüketicilerin gözünde geleneksel gıdalar, büyük ebeveynlerinin hâlen tükettiği, iyi bilinen, mevsime bağlı ve sık yenilen gıdalardır. Bu gıdaların otantik reçeteleri ve özel tatları vardır, kullanılan ham maddelerin otantik bir kaynağı bulunur ve bu ham maddeler genellikle büyük ebeveynlerinin uyguladığı yöntemlerle mamul gıdaya dönüştürülür. Ayrıca, geleneksel gıdaların otantik üretim prosedürleri bulunur. Geleneksel gıdalar yerel, doğal ve az işlenmiş gıdalardır; bir hikayeleri vardır ve genellikle özel kutlamalarla ilişkilendirilir. Bu gözlemler doğrultusunda geleneksel gıdaların tüketici algısına dayanan tanımı şu şekilde yapılabilir: "Geleneksel bir gıda ürünü, sıklıkla tüketilen veya belirli kutlamalar ve/veya mevsimlerle ilişkilendirilen, normalde bir nesilden diğerine aktarılan, gastronomik mirasa göre belirli bir şekilde özenle yapılan, çok az veya hiç işleme/manipülasyon yapılmayan, duyusal özellikleri nedeniyle ayırt edilen ve bilinen bir yerel alan, bölge veya ülke ile ilişkilendirilen bir üründür." (Weichselbaum ve ark., 2009). Bu tanıma göre geleneksel gıdalar, kültür ve sosyoloji ile derin bağları olan gıdalardır. AB'de diğer yandan Coğrafi İşaret tescili ile geleneksel gıdaların yerelliğinin korunması konusunda önemli adımlar atılmaktadır.

Türkiye'de de benzer kaygılarla geleneksel gıdaların bir envanterinin oluşturulması amacıyla bir sempozyum serisi başlatılmıştır (Çoksöyler, 2004 ve Çoksöyler, 2009). Bu sempozyumlar serisi ile Geleneksel Gıdalarımızı kayıt altına alma çabası, onların Ci tescil sürecinde de kullanılacak yararlı veriler sağlamaktadır. Yine Ci tescilleri için söz konusu geleneksel gıdaların yerelliğine ait hikayeler ve hayatın bir parçası oluşuna dair belgeler, geleneksel gıdaların sosyal boyutunu da ifade etmektedir.

Geleneksel Gıdalar Sempozyumu serisi incelendiğinde, tanıtılan bazı geleneksel gıdanın yukarıda belirtilen tanıma uyan bir sosyal boyutu olduğu açıkça görülmektedir. Bu boyut, çoğu zaman doğrudan yazılmamış olsa da pek çok çalışmada vurgulanmaktadır. Aşağıda, bu sosyal boyutu açıkça ortaya koyan bazı çalışmalara yer verilmiştir. Örneğin, Mardin yöresinde şehriye, bulgur, pestil, pekmez ve cevizli sucuk gibi geleneksel kışlık gıdaların hazırlanması sırasında komşuların birbirleriyle yardımlaşarak gösterdikleri sosyal dayanışma, gıdanın bir dayanışma nesnesine dönüşmesini sağlamaktadır (Değer ve Albayrak, 2004). Kars'ta ise kremalı kurut (Çetinkaya, 2004) ve kış yoğurdu, kuru yoğurt gibi geleneksel gıdaların mevsimselliği ile ilgili önemli bir örnek sunulmaktadır. Bu gıdalar, sütün bol olduğu dönemlerde yapılır ve yıl boyunca ihtiyaç duyulduğunda kullanılmak üzere saklanır. Benzer bir ürün olarak "Peskütan yoğurdu" adıyla Sivas'ın Kangal ve Zara ilçelerinde çorba için kullanılacak yoğurt olarak yapılmakta ve saklanmaktadır (Önay Derin ve ark., 2014).

Pişmaniyenin 1600'lü yıllarda Ermenistan ve İran'dan Anadolu'ya gelişi, ilk defa Kocaeli, Kandıra'da Hacı Agop Dolmacıyan tarafından yapılmaya başlanması, bu gıdanın bir hikâyeye dayanan kültürel mirasını pekiştiren örneklerden biridir (Karaman ve Ark., 2004). Benzer şekilde, bozanın 8000-9000 yıllık geçmişi ve Doğu Anadolu'da yapıldığına dair kaynaklar, Xenophon ve Kaşgarlı Mahmut'tan yapılan alıntılarla açıklanmaktadır (Tamer ve Çopur, 2004).

Öndül ve Albayrak (2004), aşurenin hikayesini anlatırken, bu gıdanın din ile olan bağını detaylı bir şekilde incelemişlerdir. Boran Albayrak (2004) ise**,** Karadeniz Bölgesi'nde hamsinin sosyal hayattaki yerini, bölgedeki sözlü kültür öğeleri (fıkralar, türküler) üzerinden anlatmıştır. Bu örnekler, geleneksel gıdaların sosyal ve kültürel bağlamdaki önemini gözler önüne sermektedir.

Geleneksel Gıdalar Sempozyumu serisinin tamamlanan altı oturumunda da çok sayıda geleneksel gıdanın toplumdaki kullanım şekilleri, ait olduğu topluluklarla olan ilişkileri ve ürün değerlendirme biçimleri yoğun bir şekilde ele alınmıştır (Çoksöyler, 2012). Çoksöyler, yaptığı iki derlemede, geleneksel gıdaların sosyolojik, sürdürülebilirlik, coğrafya ve din ile olan bağlantılarına dair örnekler sunmuştur. Özellikle, Doğu Karadeniz Bölgesi'nde yağışlı iklim nedeniyle kurutma yapılamazken, her türlü gıda turşu haline getirilip doğrudan yemeklerde kullanılmaktadır. Aynı şekilde, Mardin gibi yörelerde Müslüman halkın üzümü pekmez olarak değerlendirirken, Hristiyan halkın aynı ürünü şaraba dönüştürmesi, yerel kültürlerin geleneksel gıda üretimindeki farklılıklarını ortaya koymaktadır. Ege kıyılarında yerleşik kültürde, aynı kökenli ürünler farklı şekilde işlenerek farklı geleneksel gıdalara dönüşmektedir. Örneğin; Toros Dağları'ndaki göçerler katır sırtında taşımayı kolaylaştıran deri tulum peyniri üretirken, Ege kıyılarındaki yerleşik halk teneke tulum peyniri üretmektedir. Ayrıca, geleneksel gıda üretimindeki dayanışmanın yaygınlığı da bu çalışmalarda vurgulanan bir diğer önemli konudur. Geleneksel gıdaların üretiminde dayanışma çok yaygındır. Bunlardan birisi de bir imece yöntemi olan "değişik"tir. Değişik, Anadolu'da özellikle Yörükler arasında uygulanan bir imece biçimidir. Süt

değişiği, süt keşiği vb. isimlerle de anılmaktadır. Küçük üreticiler çok kısa bir sürede tulum dolusu peynir veya bir yayık dolusu yoğurt elde edecek kadar süt üretemezler. Anlaşan yakın komşular veya akrabalar aralarında "değişiğe girerek" her dönem sütleri bir aileye verirler. Sonra bu ailede sırası gelene aldığı borcu yine süt olarak öder. Bu alışverişte iki aile arasında aynı kap (stil, buçuk, bakraç, süt kazanı) kullanılır. Verilen sütün miktarını ölçmek için kap içindeki sütün içine dik olarak bir çubuk (süt çubuğu, çöp) batırılır. Sütün geldiği hiza bu çubuk üzerine işaretlenir. Çubuk, borcu verende kalır. Geri ödemede ise aynı kap doldurulur ve işarete kadar doldurulan süt geri ödenir ve çubuk senet gibi kırılarak atılır. Devam eden bu imeceye Anadolu 'nun çeşitli bölgelerinde rastlamak mümkündür (Çoksöyler ve Çoksöyler, 2009).

Geleneksel gıdaların şekillenmesinde coğrafyanın etkisi büyük bir rol oynamaktadır. Dünyanın farklı bölgelerinde, coğrafi koşullar, insanların beslenme alışkanlıklarını ve gıda kültürlerini şekillendiren en temel faktörlerden biridir. Örneğin, Çin'in iç kesimlerinde hububata dayalı bir beslenme alışkanlığı benimsenmişken, İç Anadolu'ya benzer iklim özellikleri taşıyan bu bölge, doğal kaynakların sınırlı olduğu yerlerden biridir. Diğer yandan, kıyı bölgelerinde, sel ve tayfun gibi felaketlere sıkça maruz kalan topluluklarda ise, her şeyin hatta evcil hayvanların bile gıda olarak kullanıldığı alışkanlıklar gelişmiştir. Bu tür bölgelerdeki yeme içme kültürleri, bazen felaketlere karşı hayatta kalma mücadelesinin bir sonucu olarak ortaya çıkmaktadır. Örneğin, biz muzu genellikle meyve olarak tüketirken, Afrika'da bu meyve ile etli yemekler yapılmaktadır. Doğu Anadolu'daki sınırlı sebze yetiştirme koşulları, bu bölgedeki beslenme alışkanlıklarını et ve süt ağırlıklı hâle getirmiştir. Oysa Akdeniz ve Ege bölgelerinde ise uzun ve ılıman bir vejetasyon süresi, sebze ve ot bolluğuna yol açmış ve bu durum bölgedeki sebze tüketiminin yaygınlaşmasını sağlamıştır (Doğu, 2009).

Bu coğrafi farklılıklar, sadece beslenme alışkanlıklarını değil, aynı zamanda toplumların kültürel ve sosyal yapısını da derinden etkilemiştir. Geleneksel gıdaların, toplumların kültürel kimliklerini yansıtan önemli birer öge olduğu görülmektedir. Geleneksel gıdalar, yalnızca bedensel bir ihtiyaç olarak tüketilen besinler olmanın ötesindedir. Bu gıdalar çoğu zaman inançlar, gelenekler ve yaşam olaylarıyla iç içe geçmiş unsurlar olarak toplumsal bağları güçlendiren bir rol üstlenir. Örneğin; doğum, evlenme ve ölüm gibi önemli yaşam olayları, çoğu zaman belirli yiyeceklerle bağlantılıdır ve bu yiyecekler, toplumu bir araya getiren bir sembol hâline gelir. Bu durum, yiyeceklerin sadece fiziksel bir ihtiyaç değil, aynı zamanda toplumsal ve kültürel bir bağ olduğunu gösterir. İnsanlar bir araya geldiğinde, mutlaka yiyecek ve içecek bulunur ve bu da beslenmenin sosyal bağlar kurma, kültürel kimlik oluşturma ve toplumsal dayanışmayı pekiştirme işlevini ortaya koyar (Hatipoğlu ve Batman, 2009).

Geleneksel gıdaların bir başka önemli boyutu ise dinlerle olan ilişkileridir. Dinsel inançlar, toplumların beslenme alışkanlıkları üzerinde önemli bir etkiye sahiptir. Hangi besinlerin yenip yenilemeyeceğini, nasıl hazırlanması gerektiğini ve hangi özel günlerde hangi yiyeceklerin tüketilmesi gerektiğini belirleyen dinî kurallar, toplumsal yapıyı daha da derinleştirir. Bu bağlamda, dini inançlar sadece beslenme alışkanlıklarını değil, aynı zamanda toplumsal normları ve değerleri de şekillendirir. Dünyadaki hemen her din, inançlarının beslenme alışkanlıkları üzerindeki etkisini açıkça ortaya koymaktadır. Bazı dinler belirli besinlerin yenmesini yasaklarken, aynı dine mensup topluluklar arasında bu besinlerin tüketimiyle ilgili büyük farklılıklar gözlemlenebilir. Bu durum, beslenmenin sadece karın doyurmakla ilgili bir mesele olmadığını, aynı zamanda toplumların dini, kültürel ve sosyal yapılarıyla doğrudan ilişkili olduğunu gösterir (Yabancı, 2009).

GGS serimizin tamamında yayınlanan yüzlerce makalenin önemli bir kısmı yukarıda örneklemeye çalıştığımız kültürel bütünlüğü de yansıtmaktadır.

Sonuç

Sonuç olarak geleneksel gıdalar; coğrafi, kültürel ve dini faktörlerle şekillenen dinamik bir yapıya sahiptir. Bu gıdalar, bir toplumun yaşam biçimini, değerlerini, inançlarını ve kültürel kimliğini yansıtan önemli araçlardır. Beslenme alışkanlıkları, sadece fiziksel ihtiyaçları karşılamakla kalmaz, aynı zamanda toplumların kültürel yapısını ve toplumsal ilişkilerini de belirler.

Geleneksel gıdalar, imalattan başlayarak tüketimin yer aldığı sofra âdetlerine kadar diğer kültür ögeleriyle iç içe geçmiş ve bir bütün oluşturmuştur. Gıda ve toplumsal yapı arasında güçlü etkileşim vardır ve bu bağlamda geleneksel gıdalar hem bireylerin hem de toplumların kimliklerini şekillendiren önemli bir faktördür. Küreselleşmenin bu bütünü yok etmesi oldukça zor ama imkânsız değildir. Bu nedenle kültürümüzün hiçbir boyutundan vazgeçmeden, geleneksel gıdaların da sembolize ettiği Anadolu kültür mozaiğini muhafaza etmek bir vatani görevdir. Bütünü anlamanın, anlayarak korumanın, koruyarak sürdürülebilir hâle getirmenin ve sürdürülebilirlik için küreselleşmenin baskınlığına karşı durabilmenin yolu, bu bütünü oluşturan parçaların temsilcisi olan tüm bilim dallarındaki araştırmacıların birlikte veya etkileşim hâlinde çalışmalarıdır. Bu etkileşimli çalışmanın en etkili materyallerinden birisi geleneksel gıdalardır. Onları koruyup kollamak ve anlamak belki de birbirimizi anlamanın bir aracı olacaktır. Belirtilen bu nedenle bu makalede disiplinler arası birlikteliğin zemini olacak, geleneksel gıdalar alanında disiplinler arası çalışma alanı olabilecek örnekler vermek amaçlanmıştır. Böylece önümüzdeki süreçte, geleneksel gıdaların envanterine yönelik her çalışmada yönelik bu bütünlüğü de dikkate alarak kültürel bütünlüğünü de bozmadan kayıt altına almanın kültürel sürdürülebilirlik adına önemine dikkat çekmeye çalışılmıştır.

Beyan

Yazar Katkı Beyanı

Fikret Nafi Çoksöyler: Orijinal taslağın yazılması

Sevda Aktoklu: Orijinal taslağın yazılması

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Medicinal Aromatic Plants Used in Family Planning Process and Evaluation of Their Social Dimension: Approach Suggestions for Rural Women

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ABSTRACT

The aim of this study is to provide general information about the medicinal and aromatic plants used during pregnancy, postpartum, and lactation periods, and to contribute to the literature. As a result of the study, it was determined that Sage (*Salvia officinalis* L.), Peppermint (*Mentha piperita* L.), Lemon balm (*Melissa officinalis* L.), and Chamomile (*Matricaria chamomilla* L.) were used to a large extent; Linden (*Tilia tomentosa Moench*), Thyme (*Thymus serpyllum* L.), Nettle (*Urtica dioica* L.), Black seed (*Nigella sativa* L.), Almond (*Amygdalus communis* L.), and Ginger (*Zingiber officinale Roscoe*) were used at a moderate level; and finally, Echinacea (*Echinacea purpurea* (L.) Moench), Garlic (*Allium sativum* L.), Turmeric (*Curcuma longa* L.), Rosemary (*Rosmarinus officinalis* L.), St. John's Wort (*Hypericum perforatum* L.), Flaxseed (*Linum usitatissimum* L.), Raspberry leaf (*Rubus idaeus* L.), and Fenugreek (*Trigonella foenum-graecum* L.) were used to a lesser extent. It has been observed that pregnant women turn to herbal products to reduce their stress levels and cope with issues such as nausea and vomiting. During the postpartum period, herbal remedies are preferred not only for alleviating stress but also for increasing milk production. However, there are important considerations regarding the use of certain herbal products during pregnancy and the postpartum period. The use of such plants may negatively affect both the mother's and the baby's health. Therefore, it is crucial for pregnant and breastfeeding women to consult a healthcare professional before using any herbal product.

Türk Tarım – Gıda Bilim ve Teknoloji Dergisi, 13(1): 221-228, 2025

Aile Planlaması Sürecinde Kullanılan Tıbbi Aromatik Bitkiler ve Sosyal Boyutunun Değerlendirilmesi: Kırsal Kadına Yönelik Yaklaşım Önerileri

MAKALE BİLGİSİ

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ÖZ

Bu çalışmanın amacı gebelikte, doğum sonrasında ve emzirme döneminde kullanılan tıbbi ve aromatik bitkiler hakkında genel bilgi vermek ve literatüre katkı sağlamaktır. Çalışmanın sonucunda; Adaçayı (*Salvia officinalis* L.), Nane (*Mentha piperita* L.), Melisa bitkisi (*Melissa officinalis* L.), Mayıs Papatyası (*Matricaria chamomilla* L.), bitkilerinin yaygın oranda; Ihlamur (*Tilia tomentosa* Moench), Kekik-Zahter (*Thymus serpyllum* L.), Isırgan Otu (*Urtica dioica* L.), Çörek otu (*Nigella sativa* L.), Badem *(Amygdalus communis L.), Zencefil (Zingiber officinale Roscoe)* bitkilerinin orta düzeyde*;* son olarak Ekinezya (*Echinacea purpurea* (L.) Moench), Sarımsak (*Allium sativum* L.), Zerdeçal (*Curcuma longa* L.), Biberiye (*Rosmarinus officinalis* L.), Sarı Kantaron (*Hypericum perforatum* L.), Keten tohumu (*Linum usitatissimum* L.), Ahududu yaprağı (Rubus idaerus L.), Çemen otu (Trigonella foenum-graecum L.) bitkilerinin ise az oranda kullanıldığı belirlenmiştir. Gebelerin, stres düzeylerini azaltmak, bulantı ve kusma gibi sorunlarla başa çıkmak amacıyla bitkisel ürünlere başvurduğu görülmektedir. Doğum sonrası dönemde de, stresin hafifletilmesinin yanı sıra süt üretimini artırmak için bitkisel çözümler tercih edilmektedir. Ancak, bazı bitkisel ürünlerin gebelik ve doğum sonrası dönemde kullanımı ile ilgili dikkat edilmesi gereken önemli noktalar bulunmaktadır. Böyle bitkilerin kullanımı gerek annenin gerekse bebeğin sağlığını olumsuz yönde etkileyebilmektedir. Bu nedenle, gebeler ve emziren annelerin, herhangi bir bitkisel ürün kullanmadan önce mutlaka bir sağlık profesyoneline danışmaları büyük önem taşımaktadır.

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Giriş

Gebelik insan hayatında önemli bir yere sahiptir. Gerek antepartum gerekse postpartum dönem anne ve bebek için önemli bir dönemdir. Bu dönemlerde yaşanabilecek sıkıntıların anne ve bebek sağlığını etkileyeceği kaçınılmaz bir gerçektir. Gebelik ve emzirme dönemlerinde tamamlayıcı tıp yöntemlerinden kabul edilen tıbbi aromatik bitkilerin kullanımı günümüzde yaygın hale gelmeye başlamaktadır. Romm (2017)'ye göre bitkiler, genel etkilerine göre; adaptogenler, alternatifler, ağrı kesiciler, bulantı önleyiciler, iltihap karşıtları, mikroorganizma karşıtları, spazm çözücüler, sıkılaştırıcılar, kalp destekleyiciler, anti-kanserojenler, safra artırıcılar vb. olarak sınıflandırılabilirken, Kadın Hastalıkları ve Doğum alanındaki etkilerine göre ise, cinsel isteği artırıcılar, adet düzenleyiciler, süt artırıcılar, hormon dengeleyiciler, yumurtalık toniklerinin, bitkisel östrojenler, doğum sancılarını başlatıcılar, rahimde sıkılaştırıcı etki gösterenler, kanama durdurucular, rahim kasılmalarını engelleyiciler, rahim dolaşımını arttıranlar ve rahim tonikleri olarak gruplandırılabilir. Aile planlamasında geleneksel yöntemlerin kullanımı, özellikle kırsal bölgelerde kültürel ve ekonomik faktörlerin etkisiyle oldukça yaygındır. Tıbbi bitkiler, doğal bir alternatif olarak bu yöntemler arasında önemli bir yer tutmaktadır ve bu durum, hem halk sağlığı hem de geleneksel bilgi birikimi açısından dikkat çekici bir araştırma alanı sunmaktadır.

Birçok kültürde, hamilelik, doğum sonrası ve emzirme (laktasyon) dönemlerinde destek amacıyla bazı şifalı bitkiler kullanılmaktadır. Bu bitkilerle ilgili bilgiler nesilden nesile aktarılmıştır. Doğumu kolaylaştırmak, kısırlık sorunlarına çözüm bulmak, süt üretimini artırmak, konjesyon ve mastiti tedavi etmek gibi birincil; kabızlık, soğuk algınlığı ve depresyonu iyileştirmek gibi ikincil amaçlarla kullanılabilecekleri ifade edilmiştir. Ancak, bu bitkisel kaynakların büyük çoğunluğu bilimsel olarak detaylı bir şekilde incelenmemiştir. Sadece geleneksel kullanımları, bu bitkilerin güvenilirliği ve etkinliği hakkında genel bir fikir sunmaktadır. Bu nedenle, söz konusu bitkilerle ilgili daha kapsamlı preklinik ve klinik araştırmalar yapılması gereklidir (Biol, Diker, Çankaya, 2022).

Materyal ve Yöntem

Bu araştırmanın materyalini gebelik ve emzirme dönemlerinde tamamlayıcı tıp yöntemlerinden kabul edilen tıbbi aromatik bitkilerin kullanımlarına yönelik veriler oluşturmaktadır. Bu derleme çalışmasında, gebelik ve doğum sonrası dönemde kullanılan şifalı bitkilerin etkinlikleri, güvenlik profilleri ve potansiyel yan etkileri incelenmiştir. Çalışmada, güncel dönemlerde yapılan klinik ve laboratuvar araştırmaları ile literatür taramaları esas alınmıştır. PubMed, Google Scholar, Scopus ve Web of Science gibi veritabanlarında yer alan makaleler, sistematik bir şekilde incelenmiş ve taranan literatürden yalnızca gebelik ve doğum sonrası dönemde şifalı bitkilerle ilgili olanlar seçilerek değerlendirilmiştir. Bitkilerin farmakolojik özellikleri, dozajları ve kullanım süreleri dikkate alınarak, ilgili çalışmaların bulguları karşılaştırılmış ve analiz edilmiştir. Ayrıca, her bitkinin gebelikteki potansiyel riskleri ve faydaları, güvenlik verileriyle birlikte sunulmuştur.

Bulgular

Adaçayı (Salvia officinalis L.*)*

Adaçayı (*S. officinalis*), tıbbi özellikleriyle bilinen bir bitkidir ve tarih boyunca çeşitli sağlık sorunlarına karşı kullanılmıştır. Adaçayının antioksidan, antiinflamatuar, antimikrobiyal ve spazm çözücü özelliklere sahip olduğu bilinmektedir (Batarseh et al., 2015). Gebelik ve doğum sonrasında sindirim sistemi rahatsızlıklarında, boğaz iltihaplanmalarında ve anksiyete gibi durumlarda da etkili olduğu gösterilmiştir (Gulcin, 2010). Doğum ve emzirme dönemlerinde adaçayı kullanımı dikkatli olunmalıdır. Adaçayı, laktasyon döneminde süt üretimini azalttığı için genellikle emziren annelere tavsiye edilmemektedir (Mazza et al., 2002). Bununla birlikte, doğum sonrası iyileşme sürecinde, rahim kasılmalarını destekleyen özelliklerinden dolayı, düşük dozda kontrollü kullanımı bazı durumlarda faydalı olabilmektedir (Vidal et al., 2007). Bununla birlikte, adaçayının yüksek dozları özellikle gebelik ve emzirme döneminde önerilmemektedir. Uterusta kasılmalar ve hormonal dengesizliklere yol açabilmektedir (Pereira et al., 2015).

Nane (*Mentha piperita* L.)

Nane (*M. piperita*) geleneksel tıpta yaygın olarak kullanılan, çeşitli tıbbi özelliklere sahip bir bitkidir. Nane, özellikle sindirim sistemi üzerinde rahatlatıcı etkiler yapar ve mide bulantısı, hazımsızlık, şişkinlik ve gaz sorunları gibi durumların tedavisinde kullanılmaktadır. Ayrıca, nane uçucu yağlarının antiinflamatuar, antimikrobiyal ve ağrı kesici özellikleri bulunmaktadır (Sabo et al., 2013). Gebelik ve doğum sonrasında zamanda sinir sistemi üzerinde yatıştırıcı etkiye sahip olup, baş ağrıları ve anksiyete gibi durumların tedavisinde de faydalanılmaktadır (Ali et al., 2008). Doğum ve emzirme dönemlerinde ise nane, dikkatli kullanılmalıdır. Emzirme döneminde, nane çayı veya nane yağı, süt üretimini olumsuz etkileyebilmekte ve bazı kadınlarda laktasyon sorunlarına yol açabilmektedir (Khadim et al., 2012). Bununla birlikte, doğum sonrası dönemde sindirim sisteminin rahatlatılması ve gaz sorunlarının giderilmesi için düşük dozlarda nane kullanımı bazı anneler için faydalı olabilmektedir (Mazzanti et al., 2004). Nane, gebelik döneminde aşırı kullanımdan kaçınılması gereken bir bitkidir. Aşırı miktarda nane, rahim kasılmalarını tetikleyebilmekte ve düşüklere neden olabilmektedir (Perry et al., 2008).

Ihlamur (*Tilia tomentosa* Moench)

Ihlamur (*T. tomentosa*), sakinleştirici, rahatlatıcı ve antiinflamatuar özellikleriyle bilinen bir bitkidir. Ihlamurun çiçekleri, özellikle stres, anksiyete ve uyku problemleri gibi durumların tedavisinde kullanılmaktadır. Ihlamur çayı, yatıştırıcı etkisi sayesinde sinir sistemini sakinleştirir ve rahatlatıcı bir etki göstermektedir (Wagner et al., 2003). Gebelik ve doğum sonrasında, iltihap önleyici ve antimikrobiyal özelliklere sahip olduğu için soğuk algınlığı ve grip gibi solunum yolu enfeksiyonlarında da faydalanılmaktadır (Hernandez et al., 2009). Ihlamur, vücutta terlemeyi artırarak, özellikle ateşli hastalıkların tedavisinde yardımcı olabilmektedir (Miroddi et al., 2013). Doğum ve emzirme dönemlerinde ıhlamur, genellikle güvenli bir bitki olarak kabul edilse de, dikkatli

kullanılması gerekmektedir. Ihlamur çayı, özellikle emziren annelerde rahatlatıcı etkisi ile stresi azaltabilmekte ve uyku problemleri yaşayan annelere yardımcı olabilmektedir (Dudley et al., 2009). Ancak, ıhlamur fazla kullanıldığında, aşırı terlemeye yol açabileceğinden, emzirme dönemindeki önerilen dozların dışına çıkmamak önemlidir. Gebelik döneminde ise ıhlamurun aşırı kullanımından kaçınılmalıdır. Çok yüksek dozlar rahim kasılmalarını tetikleyebilmekte ve düşüklere neden olabilmektedir (Rodrigues et al., 2012).

***Ekinezya* (*Echinacea purpurea* (L.) *Moench*)**

Ekinezya (*E. purpurea*) bağışıklık sistemini güçlendirmeye yardımcı olan ve enfeksiyonlara karşı koruyucu özelliklere sahip bir bitkidir. Ekinezya, özellikle soğuk algınlığı ve üst solunum yolu enfeksiyonlarının tedavisinde yaygın olarak kullanılmaktadır. Bağışıklık sistemini uyarıcı etkisi sayesinde vücudun enfeksiyonlara karşı direncini artırır ve virüslerin çoğalmasını engelleyebilmektedir (Sharma et al., 2011). Ayrıca, antiinflamatuar, antimikrobiyal ve analjezik özellikleriyle de tanınmaktadır (Goel et al., 2004). Gebelik ve doğum sonrasında vücutta iltihaplanmayı azaltarak, özellikle solunum yolu hastalıklarında faydalı olmaktadır (Roland et al., 2015). Doğum ve emzirme dönemlerinde ekinezya kullanırken dikkatli olmak gerekmektedir. Emzirme dönemindeki annelerde ekinezya, genellikle güvenli kabul edilse de, çok yüksek dozlarda kullanımı önerilmemektedir. Bazı araştırmalar, aşırı kullanıldığında anne sütü ile bebeğe geçebilecek ve bebek için zararlı olabilecek bazı bileşiklerin olduğunu göstermektedir (Cameron et al., 2013). Ayrıca, ekinezya, bağışıklık sistemini aşrı uyarması nedeniyle gebelik döneminde bazı riskler oluşturabilmektedir (Kennedy et al., 2014). Bu nedenle, gebelik ve emzirme dönemlerinde ekinezya kullanımı öncesinde bir sağlık profesyoneline danışılması önerilmektedir.

***Kekik-Zahter* (*Thymus serpyllum* L.)**

Kekik-Zahter (*T. serpyllum*), antiseptik, antiinflamatuar, antibakteriyel ve antimikrobiyal özellikleri ile bilinen, geleneksel tıpta yaygın olarak kullanılan bir bitkidir. Kekik-zahter, özellikle solunum yolu enfeksiyonlarının tedavisinde etkili olup, öksürük, bronşit, soğuk algınlığı ve boğaz ağrısı gibi hastalıkların semptomlarını hafifletmeye yardımcı olmaktadır (Bilia et al., 2008). Gebelik ve doğum sonrasında sindirim sistemini düzenleyici etkileri ile mide rahatsızlıkları ve gaz sorunlarının tedavisinde de kullanılmaktadır (Cowan, 1999). *T. serpyllum* 'un uçucu yağları, bakterilere ve mantarlara karşı etkili olup, bağışıklık sistemini güçlendirme özelliği de vardır (Martins et al., 2011). Doğum ve emzirme dönemlerinde kekik-zahter kullanımı ise dikkat gerektirmektedir. Bu bitki, genellikle emziren annelerde rahatlatıcı ve bağışıklık sistemini destekleyici özellikleri ile güvenli kabul edilse de, aşırı kullanımı önerilmemektedir. Yüksek dozlar bazı annelerde laktasyon üzerinde olumsuz etkiler yaratabilir veya anne sütü aracılığıyla bebek üzerinde yan etkilere yol açabilmektdir (Saxena et al., 2013). Ayrıca, gebelik döneminde, kekik-zahterin aşırı tüketimi, uterusun kasılmalarını tetikleyebilmekte ve düşük yapma riski oluşturabilmektedir (Tiwari et al., 2012). Bu nedenle, gebelik ve emzirme döneminde kekik-zahter kullanımı öncesinde bir sağlık profesyoneline danışılması önemlidir.

***Sarımsak* (*Allium sativum* L.)**

Sarımsak (*A. sativum*), güçlü antibakteriyel, antifungal, antiinflamatuvar ve antikanserojen özelliklere sahip bir bitkidir. İçerdiği alisin gibi bileşikler, sarımsağın mikroorganizmalara karşı etkili olmasını sağlamakta ve bağışıklık sistemini güçlendirmektedir (Rivlin, 2001). Sarımsak, aynı zamanda kardiyovasküler sağlık üzerinde olumlu etkiler yaparak, kan basıncını düşürmeye, kolesterol seviyelerini iyileştirmeye ve damar sağlığını desteklemeye yardımcı olabilmektedir (Toussaint-Smith et al., 2012). Ayrıca, antioksidan özellikleri sayesinde vücutta serbest radikallerin zararlı etkilerini azaltmaktadır (Geng et al., 2015). Sarımsak, sindirim sistemi üzerinde de faydalıdır ve gaz, şişkinlik gibi sorunları hafifletmektedir. Doğum ve emzirme dönemlerinde sarımsak kullanımı genellikle güvenli kabul edilse de, dikkatli olunması gereken bazı noktalar bulunmaktadır. Sarımsak, emziren annelerde süt üretimini artırabilmekte ancak bazı annelerde mide problemlerine yol açabilmektedir (Seok et al., 2011). Aşırı miktarda tüketildiğinde, sarımsak, kan sulandırıcı etkileri nedeniyle kanama riskini artırabilmektedir. Bu nedenle gebelik ve emzirme dönemlerinde dikkatli kullanılmalıdır (Reuter et al., 2009). Gebelik döneminde, sarımsağın aşırı miktarda tüketilmesi rahim kasılmalarını tetikleyebilmekte ve düşük riskini artırabilmektedir (Bordoni et al., 2014). Bu nedenle, sarımsak kullanımı öncesinde bir sağlık profesyoneline danışılması önemlidir.

***Zerdeçal* (*Curcuma longa* L.)**

Zerdeçal (*C. longa*), antiinflamatuvar, antioksidan, antimikrobiyal ve antikanserojen özellikleriyle bilinen bir bitkidir. İçeriğinde bulunan kurkumin bileşiği, vücuttaki iltihaplanmayı azaltmakta, hücre hasarını önlemekte ve bağışıklık sistemini güçlendirmektedir (Hewlings & Kalman, 2017). Ayrıca, zerdeçal, sindirim sistemi sağlığına faydalı olup, mide rahatsızlıkları, gaz, şişkinlik ve mide bulantısı gibi sorunları hafifletmektedir (Al-Zahrani et al., 2015). Zerdeçal, aynı zamanda beyin fonksiyonlarını desteklemekte, depresyon semptomlarını hafifletebilmekte ve kalp sağlığını iyileştirebilmektedir (Chandran & Goel, 2012). Doğum ve emzirme dönemlerinde zerdeçal kullanımı, genellikle güvenli kabul edilse de dikkat edilmesi gereken bazı noktalar taşımaktadır. Zerdeçal, gebelik sırasında aşırı miktarda kullanıldığında, uterusun kasılmaları tetikleyebilmekte ve düşük riskini artırabilmektedir (Sharma et al., 2005). Emzirme döneminde ise, düşük dozlarda kullanımı genellikle güvenli kabul edilse de, yüksek dozlar anne sütüne geçebilmekte ve bebek üzerinde istenmeyen etkilere yol açabilmektedir (Huang et al., 2016). Zerdeçalın kan sulandırıcı etkisi olduğu için, gebelik ve emzirme dönemi öncesinde bir sağlık profesyoneline danışılması önerilmektedir (Wang et al., 2018).

***Biberiye* (*Rosmarinus officinalis* L.)**

Biberiye (*R. officinalis*), antioksidan, antiinflamatuvar, antimikrobiyal ve sinir sistemi üzerinde yatıştırıcı etkiler gösteren tıbbi özelliklere sahip bir bitkidir. Biberiye, içerdiği rosmarinik asit ve diğer aktif bileşiklerle, vücuttaki iltihaplanmayı azaltabilmekte, bağışıklık sistemini

güçlendirebilmekte ve sindirim sistemi sağlığını destekleyebilmektedir (Coon & Ernst, 2004). Ayrıca, biberiye yağı, zihinsel uyanıklığı artırarak, hafıza ve konsantrasyon problemleri üzerinde olumlu etkiler gösterebilmektedir (Lund et al., 2009). Biberiye, aynı zamanda sindirim sistemi sorunlarına, baş ağrılarına ve kas ağrılarına karşı da faydalıdır (Omer et al., 2013). Doğum ve emzirme dönemlerinde biberiye kullanımı dikkatle yapılmalıdır. Biberiye, gebelik döneminde aşırı miktarda kullanıldığında, rahim kasılmalarını tetikleyebilmekte ve düşük yapma riskini artırabilmektedir (Beilke et al., 2010). Emzirme döneminde ise biberiye çayı veya yağı, genellikle düşük dozda kullanıldığında güvenlidir, ancak aşırı kullanımı süt üretimini olumsuz etkileyebilmekte ve bazı annelerde mide rahatsızlıklarına yol açabilmektedir (Hassan et al., 2014). Ayrıca, biberiye, kan sulandırıcı etkiler gösterebileceği için, özellikle kanama bozukluğu olan bireylerde dikkatli kullanılmalıdır (Tahar et al., 2015). Bu nedenlerle, gebelik ve emzirme döneminde biberiye kullanmadan önce mutlaka bir sağlık profesyoneline danışılması önerilmektedir.

***Isırgan Otu* (*Urtica dioica* L.)**

Isırgan otu (*U. dioica*), antiinflamatuvar, diüretik, antihistaminik ve analjezik özelliklere sahip bir bitkidir. Isırgan, vücuttaki iltihaplanmayı azaltarak, özellikle romatizmal hastalıklar ve eklem ağrıları gibi durumların tedavisinde kullanılmaktadır (Mandel et al., 2000). Ayrıca, idrar söktürücü etkisi ile ödemin giderilmesine yardımcı olabilmekte ve böbrek sağlığını desteklemektedir (Mikó et al., 2013). Isırgan, bağışıklık sistemini güçlendiren ve kan şekerini düzenleyen özelliklere de sahiptir (Singh et al., 2007). Bunun yanı sıra, demir ve diğer mineraller açısından zengin olan ısırgan, anemi tedavisinde de faydalıdır (Baggio et al., 2012). Doğum ve emzirme dönemlerinde ısırgan kullanımı dikkatle yapılmalıdır. Isırgan otu, emziren annelerde süt üretimini artırabilmekte ve bazı annelerde laktojenik etkiler gösterebilmektedir (Saba et al., 2013). Ancak, aşırı kullanımı, mide rahatsızlıklarına ve bağırsak problemlerine yol açabileceği için önerilen dozajda kullanılması önemlidir. Gebelik döneminde, ısırganın aşırı miktarda kullanımı rahim kasılmalarını tetikleyebilmekte ve düşük riskini artırabilmektedir (Dar et al., 2015). Ayrıca, idrar söktürücü etkisi nedeniyle gebelikte sıvı kaybına yol açabileceğinden dikkatli kullanılmalıdır. Bu sebeplerle, gebelik ve emzirme dönemlerinde ısırgan kullanımı öncesinde bir sağlık profesyoneline danışılması önemlidir.

***Çörek Otu* (*Nigella sativa* L.)**

Çörek otu (*N.* sativa), antiinflamatuvar, antioksidan, antimikrobiyal, analjezik ve bağışıklık sistemini güçlendiren özellikleriyle bilinen bir bitkidir. Çörek otunun içerdiği thymoquinone bileşiği, vücuttaki serbest radikalleri nötralize ederek hücre hasarını önlemekte ve iltihaplanmayı azaltmaktadır (Kanter et al., 2007). Ayrıca, çörek otu, sindirim sistemi sağlığını destekler, gaz ve şişkinlik gibi problemleri hafifletmekte, metabolizmayı hızlandırarak kilo kontrolüne yardımcı olabilmektedir (Amin et al., 2015). Bağışıklık sistemini güçlendirici etkisi sayesinde, enfeksiyonlarla savaşmada da önemli bir rol oynamaktadır (Al-Jaouni et al., 2013). Doğum ve emzirme dönemlerinde çörek otu kullanımı genellikle güvenli kabul edilse de, dikkat edilmesi gereken bazı noktalar vardır. Gebelik döneminde, çörek otunun yüksek dozda kullanımı, rahim kasılmalarını tetikleyebilmekte ve düşük riskini artırabilmektedir (Hadi et al., 2011). Ayrıca, emzirme döneminde çörek otunun aşırı tüketimi, anne sütüyle birlikte bebeğe geçebilecek bileşiklerin yan etkilerine yol açabileceği için dikkatli kullanılmalıdır (Sami et al., 2012). Bununla birlikte, çörek otu, emziren annelerde süt üretimini artırıcı etkiler de gösterebilmekte ancak aşırı miktarda kullanımı önerilmemektedir (Sharma et al., 2010). Gebelik ve emzirme dönemlerinde çörek otu kullanmadan önce bir sağlık profesyoneline danışmak önemlidir.

***Sarı Kantaron* (*Hypericum perforatum* L.)**

Sarı Kantaron (*H. perforatum*), özellikle depresyon, anksiyete ve uyku bozuklukları gibi psikolojik durumlar üzerinde etkili olan, antiinflamatuvar, antimikrobiyal, analjezik ve iyileştirici özelliklere sahip bir bitkidir. İçerdiği hiperisin ve hiperforin gibi bileşikler, beyindeki nörotransmitter düzeylerini düzenleyerek ruh halini iyileştirmekt ve depresyon semptomlarını hafifletmektedir (Ng et al., 2001). Ayrıca, sarı kantaron, antioksidan özellikleri sayesinde hücre hasarını engellemekte ve bağışıklık sistemini güçlendirmektedir (Sarris et al., 2016). Sarı kantaron, sindirim sistemi sağlığını iyileştirmekte ve yara iyileşmesini hızlandırmaktadır (Zhao et al., 2016). Doğum ve emzirme dönemlerinde sarı kantaron kullanımı, bazı riskler taşımaktadır Sarı kantaron, gebelik döneminde kontrendikedir. Rahim kasılmalarını tetikleyebilmekte ve düşük riskini artırabilmektedir (Barton et al., 2010). Ayrıca, sarı kantaron, doğum kontrol haplarının etkisini azaltabilmekte ve diğer ilaçlarla etkileşime girerek istenmeyen gebeliklere yol açabilmektedir (Linde et al., 2008). Emzirme döneminde ise, sarı kantaronun anne sütüne geçebileceği ve bebek üzerinde uyku bozuklukları, huzursuzluk gibi yan etkilere yol açabileceği için dikkatli kullanılması önerilmektedir (Müller et al., 2014). Bu nedenle, gebelik ve emzirme dönemlerinde sarı kantaron kullanmadan önce bir sağlık profesyoneline danışmak önemlidir.

***Melisa* (*Melissa officinalis* L.)**

Melisa bitkisi (*M. officinalis*), antioksidan, antiinflamatuvar, antispazmodik ve anksiyolitik özelliklere sahip olduğu bilinen bir şifalı bitkidir. Yapraklarında bulunan rosmarinik asit ve flavonoid bileşiklerinin, stresin azaltılması ve sindirim problemlerinin hafifletilmesinde etkili olduğu rapor edilmiştir (Akhondzadeh et al., 2003; Kianbakht ve Nassiri, 2011). Doğum ve emzirme dönemlerinde, melisa bitkisi, genellikle anksiyeteyi azaltmak ve uyku düzenini iyileştirmek için kullanılır. Süte etkin maddenin geçmesine bağlı olarak bebekte seditasyon görülebilir (WHO, 2002; Mills and Bone, 2004). Bununla birlikte, bu dönemdeki kullanımı dikkatle değerlendirilmelidir. Bazı araştırmalar, melisa bitkisinin hormonal dengeyi etkileyebileceğine dair veriler sunmaktadır (Kennedy et al., 2006). Ayrıca, melisa bitkisinin emzirme dönemindeki güvenliği ile ilgili sınırlı sayıda çalışma bulunduğu için, bu bitkinin kullanımı öncesinde mutlaka bir sağlık profesyoneline danışılması önerilmektedir (Ghazvini et al., 2018).

***Badem* (*Amygdalus communis* L.)**

Badem (***A. communis***) yağı yüksek oranda E vitamini, omega-3 yağ asitleri ve mineraller içeren, cilt sağlığı üzerinde olumlu etkiler gösteren bir bitkisel yağdır. Badem yağının anti-inflamatuar, nemlendirici ve yara iyileştirici özellikleri, ciltteki tahrişleri ve çatlakları gidermede kullanılmaktadır (Huang et al., 2012). Doğum ve emzirme dönemlerinde, özellikle cilt bakımında, badem yağı sıklıkla kullanılır. Hamilelik sırasında, karın bölgesindeki cilt elastikiyetini artırarak çatlak oluşumunu azaltmak için tercih edilmektedir (Glynn et al., 2012). Emzirme döneminde ise, badem yağı, meme ucu çatlaklarını iyileştirmek ve cildi yumuşatmak için güvenle kullanılmaktadır. Bununla birlikte, badem yağına karşı alerjisi olan bireylerde dikkatli kullanılması önerilmektedir (Liu et al., 2013). Badem yağı, genellikle topikal uygulama şeklinde kullanılsa da, gebelik ve emzirme sürecinde herhangi bir sistemik etkisi üzerine sınırlı araştırma bulunmaktadır, bu nedenle doktor önerisiyle kullanılması önemlidir.

***Keten* (*Linum usitatissimum* L.)**

Keten tohumu (*L. usitatissimum*), yüksek miktarda omega-3 yağ asitleri, lignanlar ve çözünür lif içeriği ile bilinen bir şifalı bitkidir. Özellikle antiinflamatuvar, antioksidan ve sindirim düzenleyici özelliklere sahip olduğu gösterilmiştir (Sadeghi et al., 2012). Keten tohumu, doğum öncesi ve sonrası dönemde, sindirim sistemi sağlığını iyileştirmek, kabızlık gibi yaygın sorunları hafifletmek için kullanılmaktadır. Ayrıca, keten tohumu yağının cilt üzerine uygulanması, çatlakları ve kuruluğu gidermede faydalı olabilmektedir (Sadeghi et al., 2012). Ancak, doğum ve emzirme dönemlerinde keten tohumunun kullanımı dikkatle değerlendirilmelidir. Keten tohumunun yüksek lignan içeriği, östrojenik etkiler gösterebileceğinden, hormon duyarlı durumlar açısından risk taşıyabilmektedir (Gossell-Williams et al., 2004). Bu nedenle, özellikle emziren annelerin keten tohumu kullanımını doktor tavsiyesi ile sınırlı tutmaları önerilmektedir (Boucher et al., 2009).

***Ahududu Yaprağı* (*Rubus idaerus* L.)**

Ahududu yaprağı (*R. idaeus*), özellikle kadın sağlığına yönelik faydaları ile bilinen bir bitkidir. Ahududu yaprağı, içerdiği tanenler, flavonoidler ve organik asitler sayesinde antioksidan, anti-inflamatuar ve tonik özellikler göstermektedir. Bu bitki, doğum öncesi dönemde rahim kaslarının tonusunu artırarak doğumun kolaylaşmasına yardımcı olabilmekte ve doğum sonrası iyileşmeyi hızlandırabilmektedir (Haas et al., 2009). Ayrıca, ahududu yaprağının adet düzenleyici etkileri olduğu ve bu yüzden doğum öncesi dönemde rahim kaslarını güçlendirmek için kullanıldığı bilinmektedir. Emzirme döneminde ise, ahududu yaprağının süt üretimini artırmaya yönelik geleneksel kullanımları bulunmaktadır. Ancak bu etkiyle ilgili bilimsel veriler sınırlıdır (Cameron ve Haslam, 2004). Ahududu yaprağının aşırı kullanımı, rahim kasılmalarını tetikleyebilmektedir. Bu nedenle gebelikte doktor önerisiyle dikkatli kullanılmalıdır (Rossi et al., 2006). Emzirme sırasında da, bitkinin güvenliği konusunda daha fazla araştırma yapılması gerektiği vurgulanmaktadır.

***Çemen Otu* (*Trigonella foenum-graecum* L.)**

Çemen otu (*T. foenum-graecum*), geleneksel tıpta yaygın olarak kullanılan, yüksek protein ve lif içeriğiyle bilinen bir bitkidir. Çemen otunun içeriğinde bulunan diosgenin, saponinler ve flavonoidler, anti-inflamatuar, antioksidan ve antimikrobiyal özellikler gösterir (Sadeghian et al., 2014). Doğum ve emzirme dönemlerinde, çemen otu özellikle süt üretimini artırıcı etkisi ile öne çıkmaktadır. Emziren annelerde, çemen otu genellikle laktasyonu artırmak amacıyla kullanılır ve bazı çalışmalarda bu etki desteklenmiştir (Sadeghian et al., 2014). Ayrıca, çemen otu, doğum sonrası iyileşme sürecine yardımcı olmakta ve rahim kaslarının toparlanmasına katkı sağlamaktadır (Tavakkol-Afshari et al., 2012). Bununla birlikte, çemen otunun gebelikte kullanımı dikkatle değerlendirilmelidir. Yüksek dozlarda rahim kasılmalarını uyarabilmekte ve erken doğum riskini artırabilmektedir (Khan et al., 2003). Bu nedenle, çemen otu kullanımı her zaman bir sağlık profesyonelinin gözetiminde olmalıdır.

***Zencefil* (*Zingiber officinale* Roscoe)**

Zencefil (*Z. officinale*), anti-inflamatuar, antioksidan, antibakteriyel ve sindirim düzenleyici özellikleriyle bilinen bir bitkidir. Zencefilin içeriğinde bulunan gingerol bileşeni, mide bulantısını azaltma, sindirimi destekleme ve ağrı kesici etki gösterme kapasitesine sahiptir (Bode et al., 2008). Özellikle gebelik döneminde, zencefil, sabah bulantılarını hafifletmek için yaygın olarak kullanılmaktadır. Bu konuda yapılan çalışmalar, zencefilin güvenli ve etkili bir tedavi seçeneği olabileceğini göstermektedir (Vutyavanich et al., 2001). Emzirme döneminde de zencefilin, süt üretimini artırmaya yardımcı olabileceği bazı geleneksel bilgiler arasında yer almaktadır. Ancak bu etkiyle ilgili bilimsel kanıtlar sınırlıdır (Omidvar et al., 2013). Zencefilin gebelikte kullanımı genellikle güvenli kabul edilse de, yüksek dozda alındığında, özellikle erken dönemde, uterusun kasılmaları tetikleyebilmektedir. Bu nedenle kontrollü ve sınırlı kullanım önerilmektedir (Lee et al., 2013).

***Mayıs Papatyası* (*Matricaria chamomilla* L.)**

Mayıs Papatyası (*M. chamomilla*), anti-inflamatuar, antioksidan, sakinleştirici ve sindirim destekleyici özelliklere sahip olan bir bitkidir. Papatya çiçeklerinde bulunan flavonoidler ve terpenoidler, özellikle sindirim sistemi rahatsızlıklarını hafifletme, uyku kalitesini artırma ve anksiyeteyi azaltma gibi etkiler göstermektedir (McKay ve Blumberg, 2006). Doğum ve emzirme dönemlerinde, papatya genellikle doğal bir sakinleştirici olarak kullanılmaktadır. Doğum sonrası dönemde, rahatlatıcı etkisi ile stresin azaltılmasına yardımcı olabilir ve emziren annelerde uyku düzenini iyileştirebilmektedir (Zick et al., 2011). Bunun yanı sıra, papatya çayı, mide bulantısı, gaz ve hazımsızlık gibi sindirim sorunlarını hafifletmek için de tercih edilebilmektedir. Ancak, papatyanın aşırı tüketimi alerjik reaksiyonlara yol açabileceğinden, özellikle ragweed (Ambrosia otu) alerjisi olan bireylerde dikkatli kullanılması önerilmektedir (Samaras et al., 2003). Papatya, emzirme sırasında genellikle güvenli kabul edilse de, herhangi bir bitkisel tedavi kullanılmadan önce doktor önerisi alınması önemlidir.

Çizelge 1. Doğum öncesi ve doğum sonrası dönemde kullanılan şifalı bitkilerin kullanım oranları
Table 1. Usage rates of medicinal plants used in the prenatal and postnatal period

Bitki Adı	Doğum ve Emzirme Döneminde Kullanım Oranı
Adaçayı (*Salvia officinalis* L.)	%25 - %30 (Yaygın)
Nane (*Mentha piperita* L.)	%18 - %22 (Yaygın)
Ihlamur (*Tilia tomentosa* Moench)	%15 - %20 (Orta düzeyde)
Ekinezya (*Echinacea purpurea* (L.) Moench)	%5 - %10 (Az Kullanım)
Kekik-Zahter (*Thymus serpyllum* L.)	%10 - %15 (Orta düzeyde)
Sarımsak (*Allium sativum* L.)	%8 - %12 (Az Kullanım)
Zerdeçal (*Curcuma longa* L.)	%3 - %7 (Az Kullanım)
Biberiye (*Rosmarinus officinalis* L.)	%5 - %8 (Az Kullanım)
Isırgan Otu (*Urtica dioica* L.)	%12 - %15 (Orta düzeyde)
Çörek otu (*Nigella sativa* L.)	%10 - %14 (Orta düzeyde)
Sarı Kantaron (*Hypericum perforatum* L.)	%2 - %5 (Az Kullanım)
Melisa (*Melissa officinalis* L.)	%18 - %23 (Yaygın)
Badem (*Amygdalus communis* L.)	%10 - %15 (Orta düzeyde)
Keten (*Linum usitatissimum* L.)	%8 - %12 (Az Kullanım)
Ahududu (*Rubus idaerus* L.)	%5 - %10 (Az Kullanım)
Çemen otu (*Trigonella foenum-graecum* L.)	%6 - %8 (Az Kullanım)
Zencefil (*Zingiber officinale* Roscoe)	%15 - %20 (Orta düzeyde)
Mayıs papatyası (*Matricaria chamomilla* L.)	%20 - %25 (Yaygın)

Kaynakça: McKay, D. L., Blumberg, J. B. (2006); Zick, S. M., et al. (2011); Sadeghian, M., et al. (2014); Kasper, S., et al. (2006); Bode, A. M., et al. (2008); Vutyavanich, T., et al. (2001).

Çizelge 2. Tıbbi amaçlı kullanılan bitkilere ait kullanım durumlarına ilişkin bazı notlar
Table 2. Some notes on the usage of plants used for medicinal purposes

Bitki	Gebelikte Kullanımı	Emzirme Döneminde Kullanımı	Notlar
Adaçayı (*Salvia officinalis* L.)	Tavsiye edilmez. Uterus kasılmalarını artırabilir ve erken doğuma neden olabilir.	Süt üretimini azaltabilir; dikkatli kullanılmalı.	Yüksek dozda kullanımda toksisite riski vardır.
Nane (*Mentha piperita* L.)	Mide bulantısı için düşük dozda kullanılabilir, ancak aşırıya kaçmaktan kaçınılmalıdır.	Düşük dozlarda güvenli; yüksek dozlar süt üretimini azaltabilir.	Reflüye eğilimli kişilerde sorun yaratabilir.
Ihlamur (*Tilia tomentosa* Moench)	Genel olarak güvenli kabul edilir; rahatlatıcı etkisi için kullanılabilir.	Genel olarak güvenli kabul edilir.	Kan basıncını etkileyebileceği için dikkat edilmelidir.
Ekinezya (*Echinacea purpurea* (L.) Moench)	Sınırlı veri mevcut; genellikle kısa süreli kullanımlarda güvenli kabul edilir.	Genel olarak güvenli kabul edilir.	Alerji riski dikkate alınmalıdır.
Kekik-zahter (*Thymus serpyllum* L.)	Yüksek dozda önerilmez; uterotonik etkiler gösterebilir.	Emzirme döneminde düşük dozlarda genellikle güvenli kabul edilir.	Antimikrobiyal etkisi vardır.
Sarımsak (*Allium sativum* L.)	Düşük miktarlarda güvenli, ancak yüksek dozda kanama riskini artırabilir.	Genel olarak güvenli kabul edilir; süt tadını değiştirebilir.	Taze sarımsak yerine pişmiş kullanımı önerilir.
Zerdeçal (*Curcuma longa* L.)	Besin olarak güvenli, ancak takviye formunda önerilmez.	Genel olarak güvenli kabul edilir.	Antiinflamatuvar etkileri nedeniyle faydalı olabilir.
Biberiye (*Rosmarinus officinalis* L.)	Yüksek dozda önerilmez; uterus kasılmalarını tetikleyebilir.	Düşük dozlarda güvenli kabul edilir.	Yüksek miktarlarda toksik olabilir.
Isırgan Otu (*Urtica dioica* L.)	Hamilelikte yüksek dozlarda kullanımı önerilmez; düşük dozda güvenli olabilir.	Genel olarak güvenli kabul edilir.	Süt artırıcı etkisi olabilir.
Çörek otu (*Nigella sativa* L.)	Düşük dozlarda güvenli kabul edilir.	Emzirme döneminde süt artırıcı etkisi nedeniyle güvenli kabul edilir.	Aşırı dozda toksisite riski vardır.
Sarı kantaron (*Hypericum perforatum* L.)	Tavsiye edilmez; doğum sırasında ve emzirme döneminde kullanılmamalıdır.	Emzirme döneminde kullanımı süt üretimini ve bebeği etkileyebilir.	Antidepresan etkileri olsa da dikkatle kullanılmalıdır.
Melisa (*Melissa officinalis* L.)	Rahatlatıcı etkileri nedeniyle düşük dozlarda güvenli kabul edilir.	Emzirme döneminde genellikle güvenli kabul edilir.	Sedatif etkisi olabilir.
Badem (*Amygdalus communis* L.)	Haricen kullanım güvenli; ağızdan alınması önerilmez.	Haricen kullanım güvenli; ağızdan alınması için sınırlı veri vardır.	Cilt nemlendirici olarak faydalıdır.
Keten (*Linum usitatissimum* L.)	Yüksek dozda uterus kasılmalarını tetikleyebilir; dikkatli kullanılmalıdır.	Emzirme döneminde genel olarak güvenli kabul edilir.	Lif kaynağı olarak faydalı olabilir.
Ahududu (*Rubus idaerus* L.)	Doğumun son aylarında kullanılabilir; uterus kasılmalarını destekleyici etkisi olabilir.	Genel olarak güvenli kabul edilir.	Sadece son trimesterde kullanılması önerilir.
Çemen otu (Trigonella foenum-graecum L.)	Sınırlı veri nedeniyle hamilelikte önerilmez.	Süt artırıcı etkisi nedeniyle emzirme döneminde faydalı olabilir.	Kan şekeri düşürücü etkisi olabilir.
Zencefil (*Zingiber officinale* Roscoe)	Hamilelikte bulantı için düşük dozlarda güvenli kabul edilir.	Genel olarak güvenli kabul edilir.	Yüksek dozlarda kanama riskini artırabilir.
Mayıs papatyası (*Matricaria chamomilla* L.)	Rahatlatıcı etkileri nedeniyle düşük dozlarda güvenli kabul edilir.	Genel olarak güvenli kabul edilir.	Alerjik reaksiyonlara neden olabilir.

Kaynakça: Mills, S., Bone, K. (2000); Tiran, D. (2010).

Sonuç

Literatür taraması sonucunda hamilelik ve hamilelik sonrası emzirme dönemlerinde kadınlar tarafından bazı tıbbi ve aromatik bitkilerin kullanıldığı belirlenmiştir. Aile planlamasında geleneksel yöntemlerin kullanımı, özellikle kırsal bölgelerde kültürel ve ekonomik faktörlerin etkisiyle oldukça yaygındır. Tıbbi bitkiler, doğal bir alternatif olarak bu yöntemler arasında önemli bir yer tutmaktadır ve bu durum, hem halk sağlığı hem de geleneksel bilgi birikimi açısından dikkat çekici bir araştırma alanı sunmaktadır. Ulcay, 2024 ile Ulcay ve Şenel (2024)'e göre; tıbbi bitkiler her zaman çeşitli hastalıkların tedavisi için düşük yan etkilere sahip kolay bir kaynak olarak kabul edilmektedir Bu çalışmada 18 bitkiye ait veriler incelenmiştir. Belirtilen bitkiler dışında da hamilelik döneminde ve hamilelik sonrası emzirme döneminde kullanılan bitkiler bulunsa da halk arasında en çok bilinenlere öncelik verilmeye çalışılmıştır. Adaçayı (*Salvia officinalis* L.), nane (*Mentha piperita* L.), melisa (*Melissa officinalis* L.), mayıs papatyası (*Matricaria chamomilla* L.), bitkilerinin yaygın oranda; ıhlamur (*Tilia tomentosa* Moench), kekik-zahter (*Thymus serpyllum* L.), ısırgan otu (*Urtica dioica* L.), çörek otu (*Nigella sativa* L.), badem *(Amygdalus communis L.), zencefil (Zingiber officinale Roscoe) bitkilerinin orta düzeyde;* son olarak ekinezya (*Echinacea purpurea* (L.) Moench), sarımsak (*Allium sativum* L.), zerdeçal (*Curcuma longa* L.), biberiye (*Rosmarinus officinalis* L.), sarı kantaron (*Hypericum perforatum* L.), keten (*Linum usitatissimum* L.), ahududu (*Rubus idaerus* L.), çemen otu (*Trigonella foenum-graecum* L.) bitkilerinin ise az oranda kullanıldığı belirlenmiştir. Burada belirtilen bitkiler gerek doğum öncesi dönemde gerekse de doğum sonrası emzirme döneminde genellikle güvenli kabul edilse de herhangi bir bitkisel tedavi kullanılmadan önce doktor önerisi alınması önemlidir. Ayrıca Özdemir'in (2021) de belirttiği kırsal alanda kadına yönelik yapılan çalışmalarda da derinlemesine nitel çalışmalara yer verilmesi büyük önem arz etmektedir.

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Prebiotic Properties of Dates and Their Impact on Health

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ABSTRACT

The date palm (*Phoenix dactylifera L.*), primarily cultivated in desert regions like the Middle East, is a significant source of nutrition, rich in sugars, polysaccharides, and bioactive compounds such as carotenoids, flavonoids, phenolics, anthocyanins, and sterols. Notably, the polysaccharides in dates exhibit prebiotic properties, supporting beneficial gut microbiota. Research highlights that dates promote the growth of helpful bacteria, including *Bifidobacterium* and *Lactobacillus*, which enhance intestinal health, improve barrier function, and increase the production of short-chain fatty acids. Beyond gut health, dates offer additional benefits, including anti-inflammatory, antioxidant, cardiovascular, neuroprotective, and blood sugar-regulating effects. This review synthesizes recent findings on the prebiotic effects and broader health impacts of dates, suggesting their potential in dietary strategies for promoting health and preventing gastrointestinal disorders.

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Introduction

The date palm belongs to the *Palmaceae* family, and *Phoenix dactylifera L.* is the scientific name for this plant, comprising two parts: seeds and edible fruit. The date palm is a valuable crop cultivated in different regions across the world, particularly in the Middle East desert areas, it had a major impact on the residents' ways of living, particularly the ancient nomads, as noted by Al-Hooti et al. (1997) and Karthishwaran et al. (2020).Due to their prebiotic properties, sugars and polysaccharides, which make up the majority of the date fruit's mesocarp, may be beneficial to gut microbes. Furthermore, date fruit contains a significant quantity of beneficial compounds including anthocyanins, phenolics, sterols, carotenoids, and flavonoids. The edible date fruit ripens through several stages before reaching its final, soft and delicious condition. The date fruit has a rich tradition in natural healing and holds significant potential for improving health (Blanco-Pérez et al., 2021; Noorbakhsh & Khorasgani, 2022).

The fiber content in date seeds ranges from 60 to 80% by weight (Al-Farsi et al., 2007). Iron, potassium, calcium, vitamin A, vitamin B3, and folic acid are among the vital components found in dates. Proteinogenic and non-proteinogenic amino acids, as well as fatty acids like oleic and linoleic acids, are abundant in dates (Ali et al., 2014; Mallhi et al., 2014). A recent study found that consuming date fruit can decrease the levels of inflammatory, oxidative, and apoptotic molecules in the body (Al-Yahya et al., 2016). In experiments involving animals, date fruits have been found to have protective effects on the liver, indicating their potential therapeutic value for a range of health issues (El Arem et al., 2014), nephroprotective kidney-protective (Al-Qarawi et al., 2008), antibacterial (Al-Shwyeh, 2019), antiviral (Ghanem et al., 2015), antioxidant and antifungal (Noshirvani et al., 2017) properties.

Over the past few years, there has been an increasing trend appreciation for the intricate relationship between diet and gut health, with particular attention given to the influence of food components on the intestinal microbiota's makeup and operation. The gut, often commonly known as the "second brain", is essential in multiple physiological functions beyond digestion, that includes immune function, metabolism, and even mood regulation (Mayer, 2011; Ross et al., 2024). Within the gut resides a complex ecosystem of trillions of microbes, generally referred to as gut microbiota, which interact with the host and with each other in a dynamic and mutually beneficial manner (Thursby & Juge, 2017).

A study revealed that natural polysaccharides show positive effects on the gut microbiome because of their prebiotic characteristics (Blanco-Pérez et al., 2021). The results of research indicate that natural polysaccharides have prebiotic properties that can beneficially influence gut microbiota (Liang et al., 2018).

This review explores the prebiotic properties of dates and their impact on intestinal microbiota, highlighting their implications for gut and overall health.

Nutritional Profile of Dates

Date palms offer notable advantages in terms of nutrition, the environment, the economy, and aesthetics. Date fruits provide abundant macro- and micronutrients at a low cost (Al-Farsi & Lee, 2008; Biglari et al., 2009). European guidelines highlight that consuming carbohydrate-rich foods with a low glycemic index is permissible when taken with suitable foods, as they can enhance blood sugar levels, such as date fruits (Alsarayrah et al., 2023).

Resh dates have a moisture content of 42.4g per 100g, whereas dried dates have a moisture content of 15.2g per 100g. Drying dates under the sun decreases moisture levels and helps to keep them fresh. The quality of drying is influenced by both humidity and temperature (Ashurst PR., 1996). Fresh dates have 54.9g of carbohydrates per 100g, while dried dates have 80.6g. Both contain high fiber and sugar content, which providing energy (Al-Farsi et al., 2005; USDA. 2023). Dates are high in ash, fat, and protein. Higher protein content is seen in dry dates (2.45g /100g) and fat (0.39g/100g) compared to fresh dates as a result of water evaporation. Values can be influenced by factors such as the conditions during drying (Table 1). The ash content is 1.67 grams per 100 grams (Al-Farsi et al., 2005; Al-Farsi & Lee, 2008; USDA. 2023).

The main sugars found in dates that are fresh and dates that are dried consist of fructose, sucrose, and glucose. Fresh dates contain a total sugar content of 43.4g per 100g, including 4.03g of sucrose, 19.4g of fructose, and 22.8g of glucose. The sugar levels in dried dates increase to 64.1g/100g, with 30.4g/100g of glucose, 29.4g/100g of fructose, and 11.6g/100g of sucrose (Ismail et al., 2006; Yousif A et al., 1982). Dates contain a range of essential minerals like iron, calcium, phosphorus, magnesium, potassium, copper, selenium, and manganese. Eating 100g of dates can supply around 15% of the recommended daily consumption of minerals. Dates are advantageous for those who have hypertension due to their reduced sodium and elevated potassium levels (Appel et al., 1997). Dried dates offer a reasonable quantity of vitamins B2, B3, B6, and B9, meeting approximately 9% of the daily allowance suggested intake per 100g. They have low levels of vitamins A, C, and B1, offering approximately 7% per 100g (Table 2) (Al-Farsi & Lee, 2008; USDA. 2023).

Research indicates that dates contain insoluble fiber. The fiber content rises from 7.5g/100g to 8g/100g during the drying process of dates. Growth in ripeness through decrease in moisture or breakdown by enzymes into soluble compounds (Thier, 1976). On average, dates contain 0.84g/100g of soluble dietary fiber, 5.76g/100g of insoluble dietary fiber, and a total dietary fiber 8g/100g (Al-Shahib & Marshall, 2002; Myhara et al., 1999; USDA. 2023). The suggested daily consumption of dietary fiber is approximately 25 grams per day (Marlett et al., 2002). Dates contain high levels of fiber, as 100g of dates can provide around 32% of the fiber that should be consumed daily. Insoluble dietary fiber has a major physiological impact on our body. Increasing stool weight can have a laxative effect, protecting our bodies from illnesses like colon cancer and diverticular disease (Marlett et al., 2002).

Phases of Dates Ripening

Date fruits undergo several developmental phases referred to as Kimri, Khalal, Rutab, and Tamar (Al-Farsi & Lee, 2008). Numerous researches has documented the chemical and physical transformations that dates experience while they progress through these phases (Table 3) (Figure 1) (Al-Farsi & Lee, 2008; Al-shahib & Marshall, 2003).

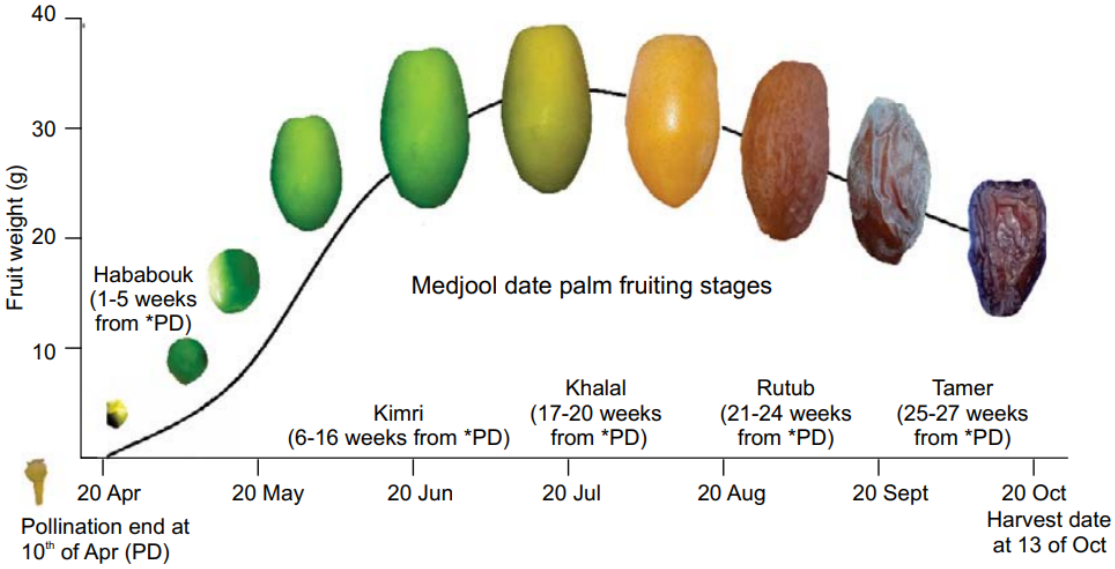

Figure 1. Various stages of Medjool date palm fruit development from pollination date (PD) to harvest (Al-hajjaj & Y. Ayad, 2018).

Table 1. Nutritional profile of dates (fresh and dried) (Al-Farsi & Lee, 2008)

Nutrient	Fresh Dates (per 100g)	Dried Dates (per 100g)
Moisture	42.4 g	15.2 g
Carbohydrates	54.9 g	80.6 g
Protein	1.5 g	2.14 g
Fat	0.14 g	0.38 g
Ash	1.16 g	1.67 g
Total Dietary Fiber	7.5 g	8.0 g
Soluble Dietary Fiber	0.84 g	0.84 g
Insoluble Dietary Fiber	5.89 g	5.76 g
Potassium	486 mg	713 mg

Table 2. Vitamin content of dried date (Al-Farsi & Lee, 2008)

Vitamin	(µg/100g)
Retinol (A)	23.85
Thiamin (B1)	78.67
Riboflavin (B2)	116.5
Niacin (B3)	1442
Pyridoxal (B6)	207
Folate (B9)	53.75
(C) Ascorbic	3900

Table 3. Ripening stages of dates

Ripening Phase	Color	Texture	Moisture Content (%)	Total Soluble Solids (TSS) (°Brix)	Key Changes
Kimri	Yellow or red	Firm	~85%	-	Increase in size, weight, and sweetness.
Khalal	Red, pink, or yellow	Firm, decreases over time	Decreases over time	30-45	Conversion of sucrose to reducing sugars (fructose and glucose), reduced astringency, slow weight gain.
Rutab	Tip begins to brown	Soft	~35%	55-60	Softening of tissues, browning of skin, further conversion of sucrose to glucose and fructose, no astringency.
Tamar	Dark brown or black	Dry	~20%	60-84	Fully mature with high sugar content, completely dried.

Kimri Phase

During the kimri Phase, dates have a high moisture content, typically around 85%. During this period, the date fruit grows larger, heavier, and sweeter. The fruit's color changes to yellow or red towards the phase's ending, based on the kind of date (El-Gioushy et al., 2022).

Khalal Phase

At this point, dates have a red, pink, or yellow color and a firm texture. The moisture level in fruit decreases over time, causing sucrose to be transformed into reducing sugars like fructose and glucose. Fruit typically has a Total Soluble Solids (TSS) ranging from 30 to 45 °Brix, with a slow weight gain and a reduction in astringency while they ripen. In certain cultivars, sucrose transformation occurs rapidly, and the fruit becomes tasty during the khalal phase (Al-Farsi & Lee, 2008).

Rutab Phase

The date tip begins to brown as it transitions into the rutab phase. fruits become lighter as they lose moisture. The fruit's current moisture level is 35%. Softening of tissues and browning of the skin also takes place during this phase. Sucrose is further converted into glucose and fructose. Dates are available without astringency and have a total soluble solids (TSS) measurement of 55 - 60 °Brix (El-Sharnouby GA et al., 2009).

Tamar Phase

Dates are completely dried when they reach the tamar stage and have a moisture content of 20%, while also being completely mature with a sugar content measuring between 60 and 84° Brix (El-Sharnouby GA et al., 2009).

Prebiotics and Their Role in Gut Health

Prebiotics, classified as non-digestible food components such as fibers and certain carbohydrates, are essential for promoting a healthy gut microbiome. Through selectively stimulating the development and activity of good bacteria, prebiotics contribute significantly to gut health maintenance. Recent research Merlo et al. (2024); Zhou et al. (2024) has shed light on their pivotal influence on modifying the makeup and activity of the gut microbiota, impacting essential aspects of human health such as immune response, metabolism, and mental well-being. Evidence suggests that regular use of prebiotic-rich foods can enhance gut barrier function, mitigate inflammation, and boost the synthesis of short-chain fatty acids, all crucial factors for optimal gut health (Holscher, 2017; Rinninella et al., 2019). Furthermore, prebiotics have demonstrated potential in alleviating indications of gastrointestinal diseases like inflammatory bowel disease (IBD) and irritable bowel syndrome (IBS), as well as aiding in the management of obesity (Gibson et al., 2017).

Prebiotics are essential elements of the diet that specifically promote the development and function of helpful gut bacteria, thereby conferring numerous health benefits. These non-digestible fibers and carbohydrates serve as substrates for the fermentation process carried out by beneficial gut microbes, leading to the process that yields butyrate, propionate, and acetate, three short-chain fatty acids (SCFAs). SCFAs operate as pivotal role in maintaining gut barrier integrity, regulating immune function, and modulating energy metabolism (Du et al., 2024; Hill et al., 2014). Furthermore, prebiotics encourage the development of particular advantageous bacterial strains, such as *Lactobacilli* and *Bifidobacteria*, which are renowned for their anti-inflammatory and immunomodulatory characteristics (Gibson et al., 2017).

Recent research has highlighted the possibility of dates (*Phoenix dactylifera*) as a prebiotic source, which are able to beneficially influence digestive system health by modulating intestinal microbiota. Dates are rich in dietary fibers, particularly non-digestible oligosaccharides, which can act as the basis for beneficial gut microbe, encouraging their development and activity (Al-Farsi & Lee, 2008). This prebiotic effect can lead to improved gut barrier function and enhanced production of (SCFAs), which play an essential role in maintaining gut health and reducing inflammation (Chandrasekaran & Bahkali, 2013). Furthermore, research conducted by Eid et al., (2014) demonstrated that regular consumption of dates significantly increased the profusion of good bacterial strains like *Lactobacillus* and *Bifidobacterium* in the gut, suggesting a beneficial link between date consumption and enhanced intestinal microbiota composition. These findings support the potential role of dates as a natural dietary component for promoting gut health through prebiotic mechanisms.

Impact of Dates on Gut Microbiota

The human gastrointestinal system can accommodate billions of microbes, with over 1014 bacteria of 2000 different species residing within it (Kau et al., 2011). The human intestinal microorganisms are made up of over. There are fifty bacterial phyla, the most common being *Firmicutes* and *Actinobacteria* (gram positive), *Bacteroidetes* (gram negative), *Proteobacteria*, and *Verrucomicrobia* (D'Aversa et al., 2013). Food primarily has an impact on the gut microbiome (Turnbaugh et al., 2009). Alterations in the makeup of the gut bacteria (dysbiosis) are linked to inflammation and health issues related to aging. Hence, regulating the gut microbiota is seen as a crucial strategy for managing age-related inflammation (D'Aversa et al., 2013). With high levels of carbohydrates, fiber, protein, fat, and vitamins and minerals ranging from 44–88%, 6.4–11.5%, 2.3-5.6%, 0.2-0.5%, and 15 grams, respectively, dates are a nutrient-dense and energy-boosting meal (Khan et al., 2016). Dates are rich in phenolic compounds, with high antioxidant and flavonoid levels observed across various types and ripening stages (Singh et al., 2012). Consuming dates directly or with polyphenol-rich extracts led to alterations in gut bacteria. Consuming dates can support gut health by promoting the growth of beneficial microorganisms and suppressing harmful bacteria linked to metabolic disorders (Eid et al., 2014).

The research done by Karim et al. (2024) assessed the impact of Ajwa date extract (ADE) on the Sprague Dawley rats' intestinal microbiota after they were fed a high-fat diet (HFD). Findings indicated that ADE significantly increased the prevalence of good bacteria, includes *Lactobacillus* and *Bifidobacterium*, while reducing harmful microorganisms like *Clostridium* and *Escherichia coli*. Additionally, ADE administration resulted in decreased blood glucose levels and body weight, demonstrating its potential to modulate gut microbiota and mitigate metabolic disorders associated with obesity. And in another study Eid et al. (2015) conducted in random, controlled human intervention research to investigate the effects eating palm dates on the development of microbiota and the health of the large intestine. Despite no significant changes in choose bacterial group or (SCFA) levels, dates increased bowel movements, reduced stool ammonia concentration, and decreased faecal water genotoxicity. The study suggests that date consumption may mitigate colon cancer risk without altering the microbiota significantly.

Potential Health Benefits of Dates Beyond Gut Health

Dates (*Phoenix dactylifera L.*) are not only known for their prebiotic effects and positive impact on gut health but also for a wide range of medicinal benefits that extend well beyond the digestive system. Rich in essential nutrients, antioxidants, carotenoids, procyanidins, flavonoids, phenolics, anthocyanins, and sterols, dates offer several potential health benefits that contribute to overall health (Al-Alawi et al., 2017; Baliga et al., 2011; Vayalil, 2012).

Anti-inflammatory and Antioxidant Properties

The potential antioxidant properties of date palm seeds and leaves are of particular interest due to the effectiveness of phenolic compounds in naturally combating reactive oxygen species and free radicals. These compounds help reduce oxidative damage to proteins, nucleic acids, and lipids, which lowers the risk of illness by minimizing free radical production and its harmful effects (Shahidi, 2000). Several phenolic substances, such as epicatechin, catechin, and proanthocyanidin dimers, and ferulic acid, were identified in the seeds and leaves in research by John & Shahidi (2019). The date palm (*Phoenix dactylifera L.*) was examined for its phenolic content and antioxidant activity in its seeds and leaves. The leaves had greater phenolic concentration than the seeds. Extracts demonstrated strong radical scavenging activity and inhibited cooked ground meat oxidation. Seed extracts notably inhibited DNA strand scission, while leaf extracts inhibited LDL cholesterol oxidation. In another study by Begum et al. (2024), the pharmacological potential of date seeds was explored. Activities of Pain relief, inflammation reduction, and muscle spasm prevention were evaluated using acetic acid-induced writhing, carrageenin-induced edema, and charcoal-induced spasm tests. The seeds' organic components effectively reduced pain in a dose-dependent manner, with n-hexane partition achieving notable results. In the anti-inflammatory test, the Ajwa seeds methanol extract displayed the most significant decrease in paw edema, closely following the standard drug. The examination of plant chemicals showed the existence of

flavonoids, glycosides, carbohydrates, and fats, with each extract having distinct dominant compounds. These results suggest the seeds' potential as a source of natural therapeutic agents. Butler et al. (2022) carried out a randomized controlled experiment to evaluate the impact of eating three dates every day for 16 weeks on blood sugar levels, body mass index (BMI), quality of life, and lipid levels in individuals with T2DM. The research involved 100 T2DM subjects divided into two groups: one consuming dates and the other avoiding them. Results showed that date consumption significantly improved the lipid profile by reducing total cholesterol and LDL levels. However, BMI and HbA1c levels remained unchanged. Additionally, quality of life improved significantly due to enhanced mental health. The study suggests that dates can benefit lipid profiles without impacting glycemic index because of their low glycemic content.

Cardiovascular Health

The benefits of dates for cardiovascular health are renowned. They contain important levels of potassium, magnesium, and antioxidants, which are essential for promoting heart health. Grazioli et al. (2022) has demonstrated that dates can decrease blood pressure and enhance lipid profiles, ultimately lowering the chances of developing cardiovascular diseases. Moreover, dates' high fiber content also helps in lowering cholesterol levels, promoting better heart health. Recent studies have shown that eating dates regularly can enhance vascular function and decrease inflammation, which can help maintain heart health (Barakat & Alfheeaid, 2023; Butler et al., 2022). The research carried out by Alsaif et al. (2007) aimed to assess the impacts of dates, gahwa (Arabian coffee), and their impact on lipid metabolism in hamsters with high cholesterol levels. Six groups from Golden Syrian hamsters were fed different diets, including a control chow, dates, dates with gahwa, and high cholesterol with combinations of dates and gahwa for a duration of 13 weeks. The diet heavy in cholesterol significantly increased body and organ weights and plasma lipids, while the dates diet notably reduced these increases. However, dates combined with a high-cholesterol diet elevated hepatic TC levels. Gahwa alone did not significantly impact lipid parameters. The findings suggest that dates may have beneficial effects on lipid metabolism and body weight, potentially reducing atherosclerosis risk. Another study done by Alalwan et al. (2020) carried out a controlled, randomized experiment to evaluate the impacts of consuming 3 dates a day for 16 weeks on blood sugar levels, weight-to-height ratio, overall well-being, and fat content in the bloodstream of individuals with type 2 diabetes subjects. The study involved 100 T2DM subjects divided into two groups: one consuming dates and the other avoiding them. Results showed that date consumption significantly improved the lipid profile by reducing total cholesterol and LDL levels. However, BMI and HbA1c levels remained unchanged. Additionally, quality of life improved significantly due to enhanced mental health. The study suggests that dates can benefit lipid profiles without impacting blood sugar levels because of low glycemic index.

Neuroprotective Effects

Dates *(Phoenix dactylifera L.)* exhibit neuroprotective effects because of their anti-inflammatory and rich in antioxidant capabilities. Studies show that the polyphenols and flavonoids in dates can mitigate oxidative stress and inflammation, important elements in neurological conditions like Parkinson's and Alzheimer's. Recent research suggests that date consumption can protect neurons from neurotoxicity and promote cognitive health, highlighting their potential role in preventing and managing neurodegenerative conditions(Baliga et al., 2011; Vayalil, 2012; Al-Alawi et al., 2017). Essa et al. (2015) conducted research on effects of dietary supplementation with date palm fruits, rich in antioxidants and phenolic compounds, on Alzheimer's disease (AD) progression in transgenic mice. Mice fed with 2% and 4% date supplementation showed improved memory, reduced anxiety, and enhanced motor skills compared to standard diet-fed AD mice. Levels of amyloid beta proteins, associated with AD, were significantly lower in supplemented groups. Findings suggest date fruit supplementation may mitigate AD risk or progression. The 4% supplementation demonstrated greater neuroprotective effects (Alkaabi et al., 2011; Rock et al., 2009).

Blood Sugar Regulation

Consuming dates in moderation can be beneficial for individuals who have diabetes. Dates possess a glycemic index that is relatively low and are rich in fiber, which helps to slow glucose absorption into the bloodstream, preventing significant spikes in blood sugar levels. They are also high in antioxidants, vitamins, and minerals, contributing to overall health. Research suggests that different varieties of dates have varying effects on blood sugar levels, but generally, it is recommended to limit intake to 2-3 dates per day for diabetic individuals to maintain stable blood sugar levels (Rock et al., 2009; Alkaabi et al., 2011; Vayalil, 2012; Alalwan et al., 2020). In the last in vivo research Butt (2020) research at the Postgraduate Medical Institute in Lahore investigated the antihyperglycemic and nephroprotective effects of Ajwa seed and fleshy part in rats with diabetes. The study found that the Ajwa pit significantly reduced blood glucose, urea, creatinine, and microalbuminuria markers, while also improving urine creatinine and creatinine clearance. However, the effect of Ajwa pulp was less pronounced. These results suggest that the Ajwa pit may possess strong antihyperglycemic and renal protective properties, likely because of its high level of polyphenols, bioflavonoids, and antioxidants. Abdullah & Al-boka (2022) study assessed the effects of date palm seed methanolic extract (PDS) on diabetes induced by dexamethasone in rabbits.

The research involved seven groups of rabbits receiving different treatments orally for 30 days. Results indicated significant anti-diabetic effects of PDS extract, potentially attributed to its flavonoid and fatty acid content. Pancreas tissue regeneration was observed histologically. While suggesting the extract's hypoglycemic potential, further investigation is necessary to identify its bioactive compounds and mechanisms of action (Abdullah & Al-boka 2022).

Future Trends and Perspectives on Gut

Recent research on the effects of dates fruit consumption on gut health reveals promising trends and perspectives. Studies indicate that dates possess prebiotic properties, promoting the development of advantageous gut flora like *Lactobacillus* and *Bifidobacterium* (Al-Farsi & Lee, 2008). These fruits are rich in fiber, particularly soluble fiber, which aids in digestion and contributes to a healthy gut microbiome (Sekirov et al., 2010). Furthermore, dates contain polyphenols, antioxidants that may exert anti-inflammatory effects in the gut, potentially reducing the risk of gastrointestinal disorders (Vayalil, 2012). However, more clinical trials are needed to validate these findings and elucidate the mechanisms behind the observed benefits (Bagherzadeh Karimi et al., 2020). Incorporating dates into the diet as a natural source of prebiotics may offer a feasible strategy for improving gut health and overall well-being (Fekete et al., 2024). Further investigation of the varied viral environment in the human gut offers the potential to discover new ways to comprehend gut health and disease. As our knowledge of the gut microbiome keeps developing, exploring therapeutic potential of dates fruit represents an intriguing avenue for future research (Fekete et al., 2024; Leviatan et al., 2022).

Conclusion

Dates *(Phoenix dactylifera L.)* hold significant promise as a natural dietary component for enhancing gut health and overall well-being. Rich in fibers, polysaccharides, and various beneficial compounds, dates exhibit prebiotic properties that promote beneficial gut microbiota, improve gut barrier attribute, and enhance (SCFAs) production. Beyond gut health, dates offer anti-inflammatory, antioxidant, cardiovascular, neuroprotective, and blood sugar regulation benefits. Future research should focus on clinical trials to further validate these findings and uncover the underlying mechanisms. Incorporating dates into the diet represents a feasible strategy for improving health and managing gastrointestinal disorders.

Declarations

Ethical Approval Certificate

None

Author Contribution Statement

Please indicate how each author contributed to this work and at what stage. For example:

A.A.: Literature review, investigation, conceptualization, and writing the original draft, review and editing.

M.K.B.: Supervision, conceptualization, visualization, review and editing.

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Genomic Analysis Methods of Microorganisms

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ABSTRACT

Molecular approaches used to identify bacterial species use 16S rRNA and MLST to determine the genetic linkage of bacteria; MLST characterizes clonal linkages by examining differences in various gene loci. MLVA determines the genetic relationships of bacterial strains and biovar-level differences and assesses the copy number of repeated DNA sequences. Sequencing provides genetic data by identifying DNA sequences; Sanger sequencing is the basis for next-generation approaches. CRISPR modifies the genetic code and can correct mutations or control genes using Cas9. These methods are important for identifying bacterial species and annotating genomic information. The methods used for this purpose are brought together in this study. The explanation and detailed description of the methods examined will contribute to their use in the field of microbiology.

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Introduction

Molecular techniques, especially based on nucleic acid amplification protocols, provide sensitive, rapid and quantitative analytical methods to study pathogens, including new or existing strains. Microscopic, cultural and serological techniques for viral, bacterial and protozoan agents constitute the traditional diagnostic microbiological assays to detect pathogen-specific markers in the media. However, the low specificity of these techniques, slow growth, the need for very sensitive media for growth or contamination with apathogenic and saprophytic microorganisms limit their use. Antimicrobial treatments or non-specific cross-reactions are also major problems of conventional microbiological analysis. In contrast, molecular techniques offer high specificity and sensitivity, along with rapid results, underscoring the necessity for their integration into diagnostic procedures (Gerace et al., 2022).

The methods used are basically based on the detection and analysis of specific parts of the pathogen's genome (DNA or RNA). By amplifying certain regions of DNA or RNA, it enables the differentiation of strains on the basis of genus, species and subspecies according to the target sequence. The detection and quantification of numerous pathogens using molecular methods is a standard procedure in many laboratories within the clinical field (Zhang et al., 2021) Molecular techniques have disadvantages as well as advantages. Although these techniques are methods that facilitate diagnosis, they are quite costly methods compared to traditional methods, the use of most of them in low-budget laboratories is very limited, and the need for qualified technical personnel is also required for most techniques (Liu et al., 2023). This study was prepared in order to emphasize the microbiological importance of these techniques and to gather the necessary information for the use of the methods.

Multilocus Sequence Typing

The field of bacterial genetics benefited from a significant advancement when Carl Woese and colleagues identified sequences based on the 16S rRNA gene. . This technique is widely used for the identification of species based on bacterial genetics and for the investigation of taxonomic relationships. 16S rRNA sequences are used for typing genetically closely related species. The Multilocus Sequence Typing (MLST) method was proposed in 1998, arising from the need for more precise typing of isolates to detect clonal relationships between bacteria (M. C. J. Maiden et al., 2013). The genetic variations between bacteria can be identified through the analysis of nucleotide sequences, which led to the development of Multilocus Sequence Typing (MLST), a method that examines the differences in multiple gene loci. MLST is based on the analysis of housekeeping genes. For each gene, a region of approximately 450 bases is amplified by PCR and the data obtained from MLST are visualised with a dendogram (Blanchard et al., 2018) (Figure 1).

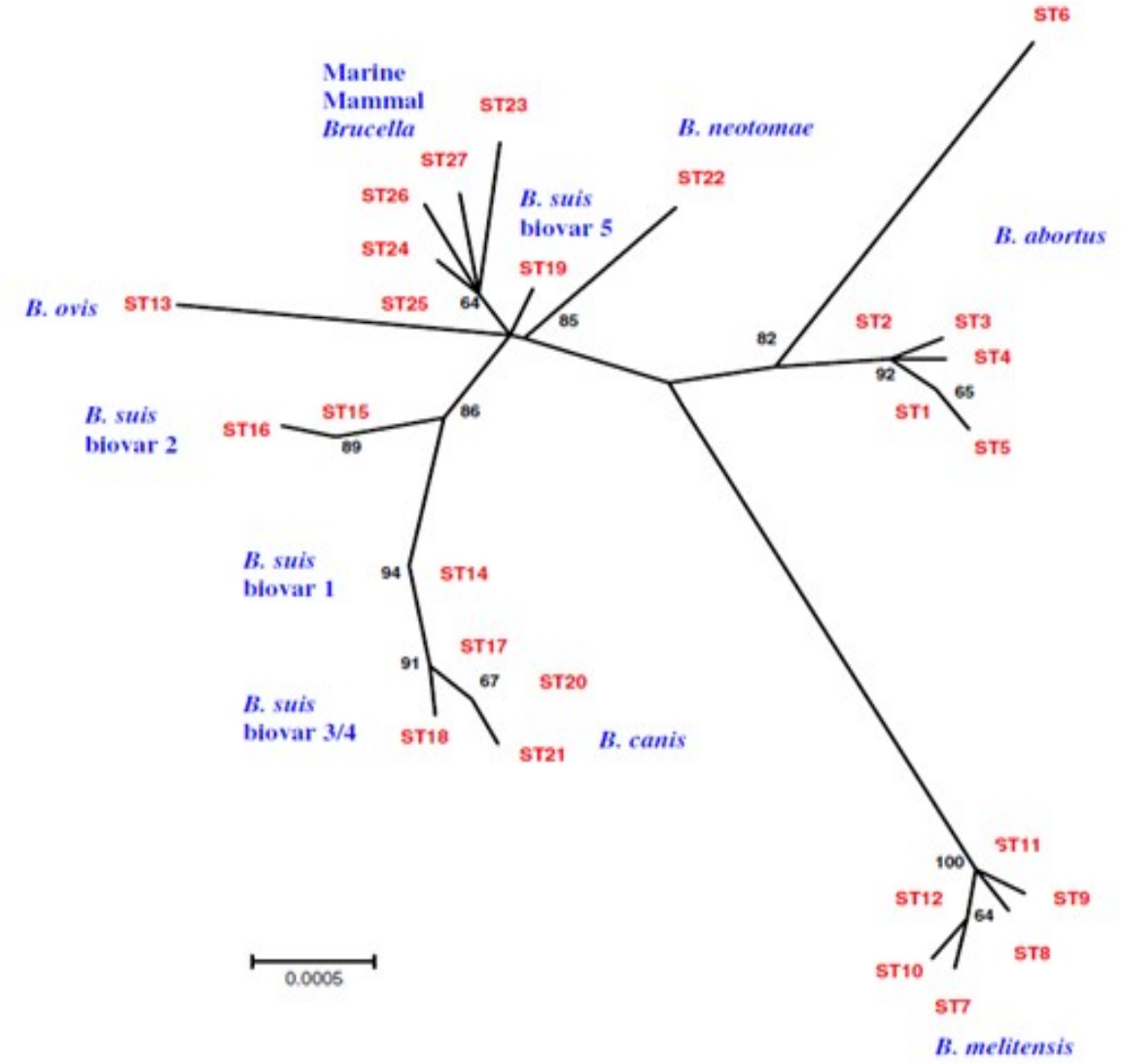

Figure 1. Phylogenetic tree of Brucella strains typed by MLST (Whatmore et al., 2007).

The MLST scheme was first developed for *Neisseria meningitidis* and subsequently applied to many bacteria and eukaryotic organisms. Since its initial discovery, MLST has been employed for a number of purposes, including epidemiological analysis of pathogens, investigation of their evolutionary history through genealogical analysis, and the study of the population structure of non-pathogenic bacteria (Feijao et al., 2018). MLST plays a critical role in the field of microbiology to systematically identify genetic variations. This method determines the genetic relationships between bacteria through the gene sequences of alleles. By comparing allele sequences, bacterial strains with similar genetic profiles can be grouped and their evolutionary relationships analysed. MLST is widely used in scientific research by making allele sequences available online through reference datasets. This method makes a significant contribution to the identification of bacterial species and a more detailed understanding of their genetic affinities (Gonzalez-Escalona et al., 2017).

One of the advantages of MLST is that it analyses fewer loci and has higher discrimination power. With this method, it is determined whether the causative agent of pandemics, epidemics and hypervirulent strains are from the same lineage by looking at the allele sequences. The identification process is fast and the newly identified allele is uploaded to the database, where different variations of the conserved gene are also detected and uploaded to the database (Pelerito et al., 2021). The sequence data used for MLST is used to analyse the degree of differences between alleles, MLST is considered the gold standard for typing bacterial pathogens. It avoids the need to analyse information at all loci and categorise which variations are due to point mutations and which are due to recombination. MLST data can also be used in sequence-based analyses as allelic variant sequences are stored with MLST data. Accommodates a variety of variations as it covers both close and distant pedigrees (Liu & Chen, 2021).

Many MLST databases are available (PubMLST, MLST homepage, Institut Pasteur MLST databases). These databases allow comparison of data from different laboratories (Jolley et al., 2018). MLST can detect subtle changes in DNA compared to other genotyping methods and enables serotyping with sequence data. It is easily reproducible and does not require special reagents. Since MLST is a PCR-based method, direct access to live bacterial isolate or high quality genomic DNA is not required. The data obtained are easily accessible on the internet (Ibarz Pavón & Maiden, 2009).

MLST is very difficult to develop dendograms except for closely related bacteria, due to the differences in "housekeeping genes" in different bacteria. Even within genera there should be multiple MLST schemes targeting different loci. MLST cannot distinguish between asexual pathogens such as *Bacillus anthracis* and *Yersinia pestis*, which have single-stranded DNA, or pathogens believed to be of the same lineage. Furthermore, this system is costly and complex to implement, particularly in low-budget laboratories (M. C. Maiden et al., 2013).

Multi Lokus Variable Number Tandem Repeat Analysis

Multi Locus Variable Number Tandem Repeat Analysis (MLVA) is a powerful method that detects strains at the biovar level and is used to evaluate genetic relationships between strains of the same species. The first study on the use of MLVA, an effective molecular typing method, was conducted in 1977 by Van Belkum et al. (Belkum et al., 1997). It is one of the preferred methods in local epidemiological studies and in the detection of the causative agent of epidemics. MLVA, which is used to categorise bacterial strains according to their subtypes, detects the number of copies of repeated DNA sequences distributed throughout the bacterial genome. While the difference in the number of consecutive repeats is usually observed in epidemiologically unrelated strains, this is preserved in epidemic-associated strains of the same lineage. The number of consecutive sequence repeats at a given locus varies from strain to strain, with variable number sequence repeats (VNTR) for a given bacterium being present in more than one locus or region. Therefore, loci of isolates from epidemically different sources differ in size and number of sequential repeats (Pontieri, 2016).

The initial step in applying this technique is to amplify Variable Number Tandem Repeat (VNTR) loci. This is followed by the targeted amplification of repeat regions using PCR. The resulting PCR products are then loaded into either agarose or automatic capillary electrophoresis and separated into DNA fragments. The number of consecutive sequence repeats is then determined based on the size of the separated DNA fragments, and an MLVA profile is created with the number of consecutive sequence repeats (Figure 2). MLST provides a great advantage for determining genotypic differences between closely related isolates when evaluated by capillary electrophoresis. It is also a very advantageous method for rapidly analysing changes in VNTR regions and determining the short-term evolution of bacteria due to storage conditions (Mirkalantari et al., 2021). There are also some disadvantages such as the high cost of the MLVA process, the need for sufficient technical personnel to interpret the results of the analyses and the difficulty of comparing the results between laboratories (Stoikov et al., 2020).

The databases and analysis platforms where MLVA results are stored and published include (www.minisatellites.u-psud.fr/MLVAnet), (www.pasteur.fr/mlva), and (www.pulsenetinternational.org/protocols). These databases and analysis platforms, which are part of the PulseNet international network, are currently in use. They allow for the comparison of MLVA profiles of strains worldwide and the determination of the geographical and temporal distribution of bacterial pathogens (Simar et al., 2021).

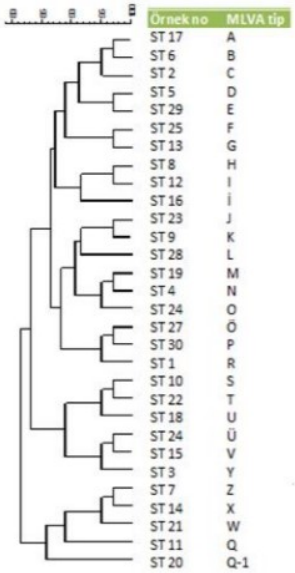

Figure 2. Dendogram of MLVA results (Savaş, 2020).

Sequencing

Sequencing is the determination of nucleic acid sequences in the polynucleotide chains that make up DNA. Sequencing allows the discovery of information about the hereditary and biochemical properties of life. Sequencing is of great importance in biological research (Heather & Chain, 2016) The history of sequencing began with the discovery of DNA. Sequence analysis was first applied to a yeast cell in 1965 (Matthews & Vosshall, 2020). Based on this work, new methods were developed. The Sanger sequencing method, discovered by Sanger et al. in 1977, was used extensively until a new generation of sequence analysis methods were discovered, and then automated systems were introduced (Fridman et al., 2021). With the discovery and subsequent widespread use of PCR technology, genome mapping studies have also gained momentum. In DNA sequencing studies with automated systems initiated by The Institute for Genomic Research (TIGR), 337 human genes, *Haemophilus influenzae, Mycoplasma genitalium, Escherichia coli* and *Bacillus subtilis, Saccharomyces cerevisiae*, Drosophila melanogaster (fruit fly) and many other organisms have been sequenced (Matthews & Vosshall, 2020).

While all these studies are continuing, studies have started for technological methods that are alternatives to the Sanger sequencing method which is used intensively. Because the Sanger sequencing method works with fewer samples and at the same time it works more expensive by making shorter readings with lower sensitivity (Barba et al., 2014).

The sequencing technique can be broadly categorised into two main groups: traditional and next generation sequencing methods.

Traditional Sequencing Techniques

Sanger Sequencing Method

This technique is called chain termination reaction. In order to apply the technique, single-stranded mould DNA, dNTPs, ddNTPs, DNA polymerase and primer containing a free OH group are required.

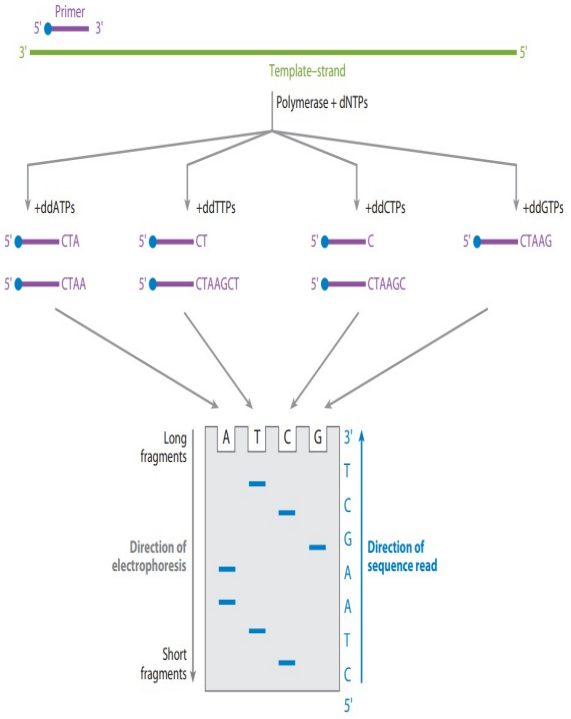

Figure 3. Visual explanation of Sanger sequencing method (Mardis, 2013).

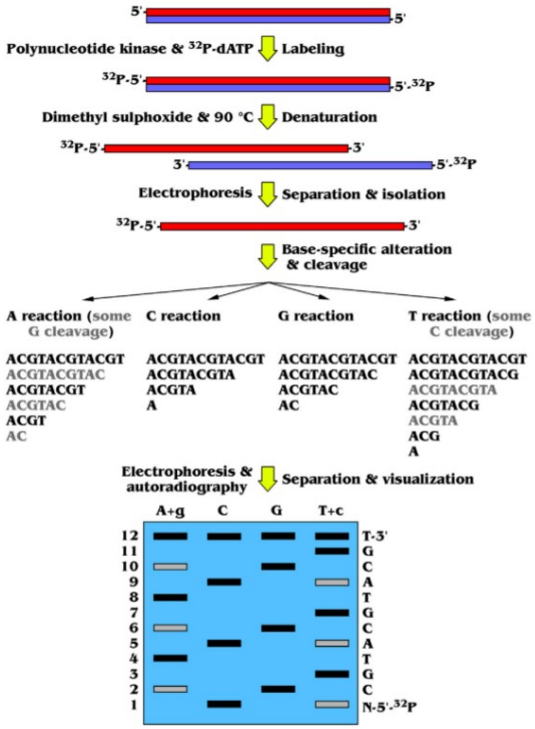

Figure 4. Visual explanation of Maxam-Gilbert method (Dorado, Gálvez, Budak, Unver, & Molina, 2019).

The most important part of this method is dideoxynucleoside triphosphates, because they do not carry an OH group and prevent the formation of phosphodiester bonds, thus the necessary environment for the binding of nucleotides is not created. Therefore, the elongation of the DNA chain is terminated and the reaction cannot continue. The mould DNA is stained with labelled dNTP to make its readings more effective. As a result, the sequence is terminated, and since the sites of these terminations are of various lengths, these fragments are assembled and sequenced (Taishan et al., 2021) (Figure 3).

Maxam-Gilbert method

This method, known as chemical sequencing, was discovered by Allan Maxam and Walter in 1977. The method first starts with radioactive labelling of the 50-P ends of double-stranded DNA (dsDNA) with 32P-dATP using polynucleotide kinase. The DNA is then denatured with dimethyl sulfoxide (DMSO) at 90°C, the resulting single-stranded DNA (ssDNA) molecules are separated by polyacrylamide gel electrophoresis into ssDNA fragments and visualised by autoradiography (Figure 4). The Maxam-Gilbert sequencing method has become the methodology of choice as it allows direct sequencing of purified DNA without the previous steps of in vivo cloning and ssDNA preparation. While this method was extensively used at the time of its discovery, its use has declined due to the use of hazardous chemicals and technical difficulty in its application (Dorado, Gálvez, Budak, Unver, & Molina, 2019).

Next Generation Sequencing Methods

Next generation sequencing (NGS) is a sequencing method developed against the disadvantages of traditional methods. Next-generation sequencing is a high-read, high-throughput and faster DNA sequencing technology that can sequence multiple DNA sequences in a single reaction. NGS usually consists of three steps: the first step is the fragmentation of DNA; the second step is the preparation of a library followed by ligation with specific ligands; the library is amplified by PCR to increase its volume; Finally, fluorescently labelled nucleotides and DNA polymerase are added for sequencing (Analara et al., 2023). NGS sequencing with fluorescent reflections of labelled fluorescently labelled nucleotides gives readings similar in shape to real time PCR.

NGS (Next Generation Sequencing) is a groundbreaking DNA sequencing method. It allows large amounts of parallel sequencing, sequencing billions of DNA fragments simultaneously. An NGS platform has the ability to process and isolate thousands or millions of different DNA samples in a single response. This approach allows for the rapid and efficient examination of vast quantities of genomic material (Robert Thomas, 2021).

The high throughput of NGS enables a variety of genetic analyses. For example, an NGS system can sequence thousands of genes simultaneously. Furthermore, a large number of patient samples, each labelled with a distinct tag, can be combined into a single response and then digitally separated using computer software. . It is particularly important for understanding the genetic characteristics of inherited disorders and complex diseases (Dubbink et al., 2014).

The versatility and high performance of NGS provide researchers with important contributions in genetic analysis studies. It offers a wide range of uses, from genomic studies to personalised medical treatments, and enables faster and more comprehensive collection of genetic data (Amanda & Robert, 2019).

There are several NGS methods and operating principles (Table 1.)

Table 1. NGS techniques used and working principle (Dorado, Gálvez, Budak, Unver, & Hernández Molina, 2019)

NGS techniques	Principle of working
Roche 454 life sciences emulsion-pcr sequencing	Random dsDNA fragments are nebulized, immobilized on streptavidin-coated beads, and subsequently denatured to isolate ssDNA, which is then amplified via emulsion PCR with biotinylated primers and read out using a glow-generating reaction, followed by genome assembly using bioinformatics tools.
Illumina reversible terminator sequencing	Illumina is defined as reversible terminator sequencing. It generates much greater genome coverage, albeit with shorter reads of 35-150 b. The technique is based on the generation of random dsDNA fragments by nebulisation, the addition of 'Y' adapters to the ends of the generated DNA fragments and hybridisation with a primer attached to a solid support.
Life technologies solid sequencing	DNA is fragmented by nebulization and adapters are ligated to the ends, followed by capture of single dsDNA molecules on primer-coated beads within a water-in-oil emulsion, leading to amplification, denaturation, and immobilization of ssDNA on a glass surface with blocked OH ends; subsequent sequencing via SOLiD involves ligation and fluorescent detection using labeled primers.
Life technologies ıon torrent chip sequencing	dsDNA is fragmented via nebulization, with adapters ligated to the ends, followed by capture of biotin-labeled dsDNA on streptavidin-coated beads using biotincontaining adapters; subsequent isolation of non-biotinylated ssDNA through denaturation, amplification via EmPZR with biotinylated primers, and genome assembly through read alignment using bioinformatics tools.
Helicos biosciences true single-molecule sequencing	DNA is randomly fragmented via nebulization, followed by denaturation and labeling of OH ends with fluorescent tags, enabling detection of labeled ssDNA on a solid support and subsequent light emission during polymerization with fluorescent dNTPs in billions of parallel reactions on flow cells, facilitating assembly of reads into chromosomes and genomes using bioinformatics tools.
Pacific biosciences single-molecule real-time sequencing	Rolling Circle Amplification (RCA) and Multiple Displacement Amplification (MDA) utilize loop adapters to convert dsDNA fragments into ssDNA, followed by incorporation of fluorescent nucleotides during polymerization to enable real-time sequencing in nanophotonic chambers for high-throughput readouts.
Complete genomics combinatorial probe-anchor ligation(cpal) sequencing	A library of randomly fragmented DNA with semi-adapters is first generated through autoligation and off-target cutting methods. Subsequently, ssDNA NanoBubbles (DNB) are created via clonal ssDNA RCA amplification, where fluorescence signals from bound probes are split and detected, enabling parallel reactions on millions of color-coded probes for genome assembly into chromosomes using bioinformatics tools.
Oxford nanopore technologies sequencing	Oxford Nanopore Technologies detects nitrogenous base residues of free nucleotides or nucleic acid polymers on a silicon chip via nanopores, analysing ssDNA from nebulized, digested dsDNA through ion current variations; this high throughput process enables sequencing reads to be assembled into chromosomes and genomes using bioinformatics tools.

Clustered Regularly İnterspaced Short Palindromic Repeats

Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) is an important technology that can be used to edit genes within sequencing techniques, basically with a gene editing approach. CRISPR is based on the logic of finding a specific DNA fragment in the cell, modifying and rearranging it. However, CRISPR also has functions such as turning genes on or off without changing sequences (Horodecka & Düchler, 2021). CRISPR allows cells to be fingerprinted and recorded by decoding the genetic code. It thus clarifies the evolutionary process (K. S. Makarova et al., 2011). The key to CRISPR is the many variants of "Cas" proteins found in bacteria and known to help defend against viruses (Jansen et al., 2002). The Cas9 protein is the most widely used protein by scientists. This protein can be easily programmed to find and bind to the desired target sequence. The most important function of the CRISPR-Cas system is the elimination of mutations. The mechanism that accomplishes this function consists of several steps. In the first step, when the Cas protein is introduced into the cell along with the guide RNA, it travels along the DNA strands until it combines with the RNA and discovers and binds to a DNA sequence 20 nucleotides long. CRISPR and the bound RNA then identify the target sequence, in the next step the faulty genetic material is cut by CRISPR-linked nucleases. Finally, the cut is repaired, removing the mutations that render the gene inoperable (Hale et al., 2012; Kira S. Makarova et al., 2011). This process is referred to as genome editing or gene editing and represents the most prevalent application of CRISPR.

Conclusion

Next-generation techniques offer significant advantages in microbiology, replacing many traditional methods. In particular, Next Generation Sequencing (NGS) has revolutionized microbiological diagnostics and epidemiological studies by genomic characterization of

pathogens. Studying pathogens with NGS allows their genetic structure to be determined in detail. This allows for greater precision and accuracy in the identification and classification of pathogens. It also plays a critical role in identifying antimicrobial resistance mechanisms and helps determine appropriate treatment options. In epidemiologic studies, next-generation methods are an extremely powerful tool for identifying the source and spread of infections. For example, they can be effectively used to detect and monitor outbreaks of nosocomial infections such as MRSA. While it can be very difficult to understand interspecies relationships with traditional methods, next-generation techniques can clearly reveal the isotypes and relationships of pathogens. Next-generation techniques are of great importance in the diagnosis of bacteria that take a long time to culture or are difficult to culture. As a result, next-generation methods offer significant advantages over traditional methods in critical areas such as microbiological diagnostics, drug resistance monitoring and infection control. The development of these technologies is considered a revolutionary advance in microbiological diagnostics and epidemiological monitoring.

Declarations

Conflict of Interest

The authors declare that they have no conflict of interest.

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