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Morphological and Phenological Attributes of Chickpea (*Cicer arietinum* L.) Affected by Different Growing Conditions, Zeolite and Nitrogen Applications

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A R T I C L E I N F O

Research Article

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A B S T R A C T

The present study investigated the effects of two different zeolite applications and different nitrogen-based fertilizers on chickpea's yield and yield components in dry and irrigated conditions. The field experiment was conducted during 2019 and 2020 in the experimental area of the Faculty of Agriculture, Eskisehir Osmangazi University, Eskisehir, Türkiye. The experimental design was a split-split plot with four replicates. The main plots were grown under dry-irrigated conditions. At the same time, subplots received zeolite applications (zeolite^{+}- zeolite^{-}), and sub-sub plots received nitrogen applications [control, traditional, chemical, farmyard manure, and Isabion, (an animal collagen-derived biostimulant)]. The experiment found that irrigation caused a delay in phenological characters but had a favorable impact on morphological characters and yield. The effect of zeolite applications was different in the first and second years of the experiments for the investigated characters. In the first year, the application of zeolite had a significant impact on grain yield, but there was no discernible effect in the second year. The experiment demonstrated that both chemical fertilizer and farmyard manure positively impacted phenological and morphological characteristics. In both years, the farmyard manure plots produced the highest grain yield. Farmers in Türkiye are advised to apply nitrogen to their crops as the profitability of chickpeas has risen in recent years. If the high cost of farmyard manure renders its use impracticable, farmers can opt for chemical fertilizer as an alternative.

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Introduction

Pulses have been extensively grown crops from prehistoric times across the globe. They provide a substantial amount of protein, dietary fiber, and minerals, and have numerous health advantages (Kaur & Prasad, 2021). Studies on legumes have demonstrated their significance in preventing diseases such as type 2 diabetes, cancer, cardiovascular disorders, and obesity. Chickpeas (*Cicer arietinum* L.), often known as garbanzo beans, are a type of leguminous food that has been valued for its protein content and has been a significant source of nutrition for humans for a long time (Gupta et al., 2017). Within agricultural systems, it functions as a substitute for fallow in cereal rotations, hence promoting production sustainability and diminishing the requirement for nitrogen fertilization by fixing atmospheric nitrogen.

The extensive utilization of synthetic fertilizers in agricultural activities leads to numerous environmental issues. Ammonia volatilization is the primary factor responsible for nitrogen depletion in agricultural systems on a global scale (Bouwman et al., 2002). Zeolites are a class of hydrated aluminosilicate minerals that possess an unending three-dimensional crystal lattice. They consist of cations derived from alkaline elements and alkaline soil elements, together with other less frequently occurring cations (Jarosz et al., 2022). Zeolites have a high porosity in their crystalline structure, allowing them to retain water molecules that make up to 60% of their weight (Mumpton, 1985). Zeolites can alter the amount of water in the soil by changing its bulk density and aeration porosity (Ramesh & Reddy, 2011). Zeolites have been utilized in agriculture since the 1960s because of their efficacy as soil additives for promoting plant growth, their ability to exchange cations, and their capability to release fertilizers gradually (Vassilina et al., 2023). In their study, Sangeetha and Baskar (2016) found that zeolites have a high level of selectivity for the ammonium cation (NH_4^+). As a result, the use of zeolites can help reduce ammonium loss.

Farmyard manure not only supplies soil with essential nutrients for plants but also enhances its physical characteristics. It increases the quantity of organic matter and promotes microbial activity in the soil. Farmyard manure contains a high concentration of organic matter and essential plant nutrients. Organic fertilizers are also the source of nitrogen for plants (Karayel et al., 2020) and nitrogen can be bound by organic compounds.

Biostimulants enhance plants' resilience to abiotic stressors by promoting plant growth and development. They have been employed in agriculture as a viable substitute for synthetic fertilizers to enhance the productivity and nutritional quality of food crops. Biostimulants enhance nitrogen assimilation by stimulating the initiation and transcription of nitrogen metabolism (Ertani et al., 2009). Biostimulant application significantly improved grain yield, nutrient content in plant and seed (Mukherjee et al., 2022). Gomez et al. (2024) reported that biostimulants positively affected germination in chickpea.

The aim of this work is to evaluate the influence of two different zeolite treatments and different nitrogen-based fertilizers on the morphological and phenological traits of chickpeas in both dry and irrigated conditions.

Material and Methods

The field experiment was conducted during 2019 and 2020 at the experimental area of the Faculty of Agriculture, Eskisehir Osmangazi University, Eskisehir, Turkey (39°48’ N; 30°31’ E, 798 m above sea level). Figure 1 shows climatic data for the research area. The research area experienced a long-term average rainfall of 165.6 mm and an average temperature of 16.23°C from March to August. Total precipitation for the 2019 and 2020 growing seasons was 163.9 mm and 169.5 mm, respectively. Total precipitation was close to the long-term in both years, but there were differences in precipitation distribution in months. The total precipitation in June was more than 2.5 times the long-term total precipitation in the second year of the experiment. Chickpeas are sensitive to water deficiency at the start of flowering and pod setting (Adak, 2021). As a result, the plants benefited greatly from the second year of June precipitation. The mean temperatures were 16.13°C in the first year and 16.15°C in the second year (Table 1). In the first year, the Transitional Zone Agricultural Research Institute analysed soil samples from the research area and in the second year, the New Water Soil Analysis Laboratory did so. Soil samples were taken separately from both dry and irrigated plots in both years of the experiment. In the first year, the soil sample was slightly alkaline, very low in organic matter, moderately calcareous, unsalted, low in nitrogen, high in potassium, and low in phosphorus. Dry areas have clay loam soil, while irrigated areas have loamy soil (Anonymous, 2019). In the second year, the soil sample is slightly alkaline, very low in organic matter, moderately calcareous, unsalted, low in nitrogen, potassium high, and phosphorus sufficient. It is loamy in dry areas and clay-loam in irrigated areas (Anonymous, 2020).

The experimental design was a split-split plot with four replicates. The main plots were grown under dry-irrigated conditions, subplots received zeolite applications (zeolite$^+$, zeolite$^-$), and sub-sub-plots received nitrogen applications [control, traditional, chemical, farmyard manure, and Isabion (an animal collagen-derived biostimulant)]. The Azkan chickpea variety was used as genetic material. Zeolite in the form of clinoptilolite was obtained from Manisa Gördes (Enli Mining Company). Diammonium Phosphate (DAP) (18N-46P%) was used as traditional fertilizer, and Ammonium Sulfate (AS) (21N%) + Triple Super Phosphate (TSP) (44% P_2O_5) was used as chemical fertilizer. The amount of nitrogen and phosporos in the experiment was applied at equal doses in traditional and chemical fertilization. Farmyard manure was obtained from Mahmudiye district of Eskişehir province, and Isabion was obtained from Syngenta Company. Table 2 presents some of the physical and chemical properties of zeolite, Isabion and farmyard manure.

Sowing was done at a 30 cm row spacing at a seeding rate of 60 seeds per m^2 on April 26 and 15, 2019 and 2020, respectively. The seeds were sprayed to prevent root rot and anthracnose diseases before sowing. Table 3 provides the application times and ratios of the materials used in the experiment. The experiment irrigated the plants at emergence time, before flowering, during the flowering period, during the pod formation period, and the grain filling period. Herbicide application was done for weed control. A fungicide containing 25% Boscalid and 12% Pyraclostrobin was applied against Ascochyta rabiei before flowering and before grain filling period. The harvest was done by hand in the first year, August 26, 2019, and August 23, 2020, in the second year.

For all the sub-sub plots, the number of days to emergence, days to flowering and days to maturity were determined. The plant height (cm), first pod height (cm), number of branches, and branch diameter (mm) were evaluated on 10 randomly selected plants in each sub-sub plot. Each sub-sub plot was harvested and threshing, and grain yield (kg ha^{-1}) was estimated (Tosun & Eser, 1975).

The experiments were analyzed with the MSTATC statistical programs. Means were compared by the Least Significant Differences (LSD) test (Steel & Torrie, 1980).

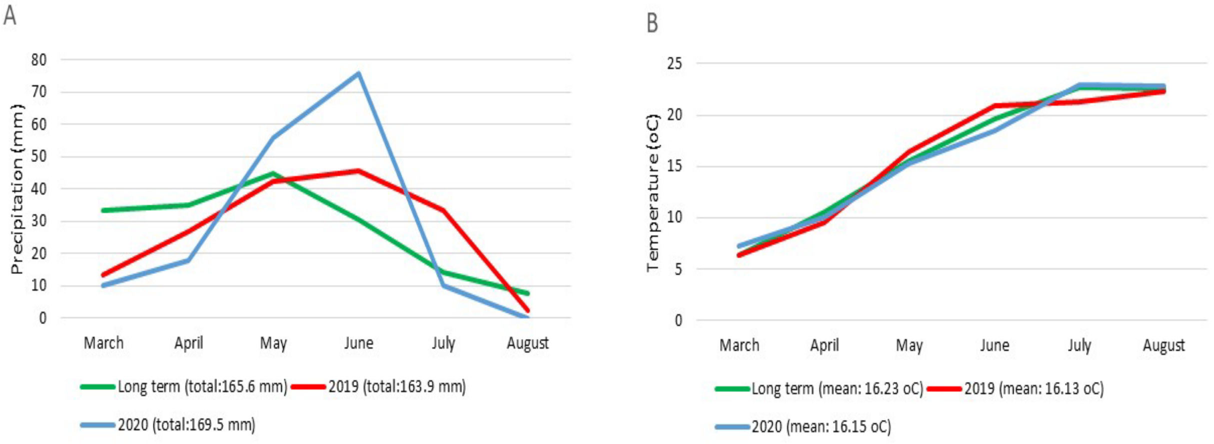

Figure 1. Climatic data of research area

Table 1. Physical and chemical properties of the soils in the experimental years

Year		Depth (cm)	pH	Lime (%)	Salt (%)	Organic matter (%)	N (%)	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	Texture
2019	Dry	0-30	7.78	5.60	0.02	0.93	0.04	23.4	2720	Clay-loam
	Irrigation	0-30	7.80	5.46	0.01	1.23	0.06	22.0	3910	Loamy
2020	Dry	0-30	8.22	6.73	0.01	1.19	0.05	62.7	3500	Loamy
	Irrigation	0-30	8.20	4.75	0.02	1.26	0.06	93.8	4430	Clay-loam

Table 2. Physical and chemical properties of zeolit, isabion and farmyard manure

Properties	Zeolite	Isabion	Farmyard Manure
Organic matter (%)	20	62	48.2
Maximum humidity	20		
pH	6-8		7.2
Organic nitrogen (%)		10	
Organic carbon (%)		30	
Amino acids (%)		11	
N(%)			1.6
P (%)			0.35
K (%)			1.8

Table 3. Application times and ratio of the materials used in the experiment.

Material	Application time	Aplication ratio
Zeolite	Before sowing	1000 kg ha^{-1}
Diammonium Phosphate (DAP)	Before sowing	140 kg ha^{-1}
Ammonium Sulfate (AS)	Before sowing	25 kg ha^{-1}
Triple Super Phosphate (TSP)	Before sowing	60 kg ha^{-1}
Farmyard manure	Before sowing	20 tons ha^{-1}
Isabion	Before flowering	3000 ml ha^{-1}

Results and Discussion

Phenological Observations (Seed germination time, flowering time, maturity time)

In the first year, the growth conditions considerably impacted both the flowering time and maturity time. However, in the second year, only the growth conditions affected the maturity time. The seed germination period was determined to be minimal in both years due to the growing conditions. In the first year of the experiment, irrigation caused a delay in both the flowering and maturity time. However, in the second year, irrigation only affected the maturity time (Table 4, 5). Oğuz & Erman (2021) found that chickpeas experienced a delay in their flowering time when exposed to high relative humidity levels. Yolcu (2008) reported that the maturity time of chickpeas was delayed by irrigation. In the second year, there was a significant amount of rainfall, especially in June. The abundant rainfall hindered the ability to observe irrigation's impact on the flowering period's duration in the second year. The use of zeolite considerably impacted flowering time and maturity time in the first year, but these effects were not significant in the second year. The effect of zeolite applications on seed germination time was statistically negligible in both years, as seen in Table 4 and 5. Applying zeolite in the first year resulted in a postponement of both flowering and maturity time. Zeolite, a type of mineral, can absorb moisture present in the soil. This property of zeolite helps decrease the negative effects of drought on plants, known as drought stress (Mahmoud et al., 2023). Nitrogen applications considerably impacted seed germination time and maturity time in the first year. However, in the second year, only maturity time was significantly affected by nitrogen applications (Table 4,5). The first year of the experiment resulted in the earliest occurrence of seed germination time in the farmyard manure plots. Akal (2016) states that using farmyard manure enhances soils' ability to absorb solar radiation, resulting in a faster warming process. Oğuz (2008) suggested raising the temperature of cold soils is advisable. Farmyard manure raises the soil's warmth. Consequently, the seed germination occurred early. The seed emergence period in the second year was not influenced by farmyard manure due to climate and soil conditions. The decreased temperature in April during the first year resulted in a more pronounced manifestation of the impact of farmyard manure. The farmyard manure plots in the first year exhibited the longest time to reach maturity, whereas the chemical plots in the second year offered the same results. In the first year, the farmyard manure assimilated moisture from the soil, delaying the maturity period. Abundant rainfall may have hindered the ability to observe the impact of farmyard manure in the second year.

Flowering time was postponed in all nitrogen applications, except in the control application, because of the water-absorbing characteristics of zeolite in the dry + zeolite$^+$ plots. Figure 2 demonstrates that using farmyard manure resulted in the most recent flowering time. Demir (2021) found that using organic fertilizers in chickpeas leads to delayed flowering compared to using chemical fertilizers. The hydrophilic nature of zeolite in the dry + zeolite$^+$ plots (Figure 2) caused a delay in the maturation period for all nitrogen treatments, except the conventional method.

Table 4. Effects of different growing conditions, zeolite applications and nitrogen applications on some traits of chickpea in 2019.

	SGT (day)	FT (day)	MT (day)	PH (cm)	FPH (cm)	NB	BD (mm)	GY (kg ha^{-1})
Dry	12.3	50.1 b	112.8 b	46.2 b	30.9	1.88 b	3.82 b	1180 b
Irrigated	12.3	52.5 a	119.0 a	48.7 a	31.7	2.05 a	4.76 a	2140 a
Mean	12.3	51.3	115.9	47.4	31.3	1.96	4.29	1660
Zeolite^{+}	12.3	51.8 a	116.3 a	47.7 a	30.7 b	1.95	4.28	1730 a
Zeolite^{-}	12.2	50.8 b	115.5 b	47.2 b	31.8 a	1.98	4.30	1590 b
Mean	12.3	51.3	115.9	47.4	31.3	1.96	4.29	1660
Control	12.5 a	50.6	116.1 b	46.5 d	30.9 c	1.91 b	4.24 b	1380 e
Traditional	12.3 a	50.6	115.1 c	47.4 bc	30.5 c	1,98 ab	3.97 c	1630 c
Chemical	12.7 a	50.4	114.9 c	48.6 a	32.6 a	2.03 a	4.35 b	1720 b
Farmyard man.	11.2 b	52.6	117.1 a	47.8 b	30.8 c	1.94 b	4.61 a	2070 a
Isabion	12.6 a	50.9	116.3 b	47.0 cd	31.5 b	1.96 ab	4.28 b	1510 d
Mean	12.3	51.3	115.9	47.4	312.3	1.96	4.29	1660
General Mean	12.3	51.3	115.9	47.4	31.3	1.96	4.29	1660
Growing cond. (A)	ns	**	**	**	ns	*	**	**
Zeolite app.(B)	ns	*	**	*	**	ns	ns	**
A × B	ns	ns	ns	ns	ns	*	*	ns
Nitrogen app. (C)	**	ns	**	**	**	*	**	**
A × C	ns	*	**	**	**	**	**	**
B × C	ns	*	**	**	**	ns	**	*
A × B × C	ns	**	**	**	**	ns	ns	ns

ns: non-significant, *: p≤0.05, **: p≤0.01. SGT: Seed germination time FT: Flowering time MT: Maturity time; PH: Plant height FPH: First pod height NB: Number of branches BD: Branches diameter GY: Grain yield

Table 5. Effects of different growing conditions, zeolite applications and nitrogen applications on some traits of chickpea in 2020.

	SGT (day)	FT (day)	MT (day)	PH (cm)	FPH (cm)	NB	BD (mm)	GY (kg ha^{-1})
Dry	12.4	67.0	130.8 b	69.4 a	34.2	2.38	6.47 b	2504 b
Irrigated	12.5	67.0	136.1 a	67.4 b	33.5	2.13	6.63 a	3253 a
Mean	12.5	67.0	133.5	68.4	33.9	2.25	6.55	2879
Zeolite^{+}	12.4	67.0	133.7	69.5 a	34.1 a	2.35 a	6.75 a	2876
Zeolite^{-}	12.5	67.0	133.3	67.3 b	33.6 b	2.16 b	6.35 b	2880
Mean	12.5	67.0	133.5	68.4	33.9	2.25	6.55	2879
Control	12.5	67.1	133.0 b	70.2 a	34.9 a	2.14 b	6.30 b	2467 c
Traditional	12.4	67.1	133.4 b	68.0 bc	33.6 b	2.45 a	6.44 b	2880 b
Chemical	12.2	66.8	134.3 a	67.2 c	32.8 c	2.27 ab	6.73 a	2867 a
Farmyard man.	12.4	67.0	133.1 b	68.1 bc	34.3 ab	2.22 b	6.91 a	3360 a
Isabion	12.5	66.9	133.6 ab	68.4 b	33.8 b	2.19 b	6.37 b	2817 b
Mean	12.5	67.0	133.5	68.4	33.9	2.25	6.55	2879
General Mean	12.5	67.0	133.5	68.4	33.9	2.25	6.55	2879
Growing cond. (A)	ns	ns	**	*	ns	ns	*	**
Zeolite app. (B)	ns	ns	ns	**	**	*	**	ns
A × B	ns	ns	**	ns	ns	ns	**	ns
Nitrogen app. (C)	ns	ns	*	**	**	**	**	**
A × C	ns	ns	ns	*	**	**	**	**
B × C	ns	ns	ns	**	**	**	**	**
A × B × C	ns	ns	ns	**	**	**	**	**

ns: non-significant, *: p≤0.05, **: p≤0.01. SGT: Seed germination time FT: Flowering time MT: Maturity time; PH: Plant height FPH: First pod height NB: Number of branches BD: Branches diameter GY: Grain yield

Among the plots tested, those with zeolite and without irrigation had the lowest values for maturity time, while the plots with zeolite and irrigation had the greatest values in the second year. Hence, the correlation between the growing conditions and the zeolite application might have played a significant role (Figure 3).

Plant Height, First Pod Height

The growing conditions considerably impacted the plants' height in both the first and second years. The first pod height was determined to have no substantial impact on the growing conditions in both years, as seen in Table 4 and 5. During the first year of the experiment, the plant height exhibited a positive correlation with the application of irrigation. Irrigation is anticipated to promote greater development of the vegetative components of chickpeas. Chickpea has drought tolerance, nevertheless, irrigation exerts a beneficial impact on the plants. Togay et al. (2005) found that irrigation or enough soil mositure led to an increase in the height of chickpea plants. The excessive amount of rainfall in the second year of the experiment hindered the ability to observe the impact of irrigation, leading to a decrease in plant height in the irrigated plots. Zeolite applications were significant for plant height and first pod height in first and second year, as shown in Table 4.5. The application of zeolite may have inhibited the leaching of plant nutrients into the soil. Consequently, plants could more readily obtain nutrients, resulting in increased plant height in the zeolite$^+$ plots. Bybordi (2016) and Amiri et al. (2021) reported that applying zeolite resulted in an augmentation of plant height. In their study, Erdin and Kulaz (2014) found a direct correlation between plants' height and the first pod in chickpeas. Nevertheless, during the first year of the experiment, the zeolite plots had a greater height for the first pod. In the second year of the experiment, the zeolite$^+$ plots had a greater height for the first pod. This outcome is anticipated. Nitrogen applications had a considerable impact on plant height and first pod height throughout the first and second years, as shown in Table 4.5. Applying chemical manure in the first year of the experiment resulted in the greatest plant height and the highest height of the first pod. According to Gul et al. (2015), plant height was greater in the chemical plots than in the control plots. In their study, Kaya et al. (2007) found that the control plot had the shortest first pod height, measuring 16.3 cm. However, the first pod height increased as the chemical fertilizer doses were raised, ranging from 18.2 cm to 19.2 cm in chickpeas. During the second year of the trial, the control plots exhibited the greatest plant height and first pod height. The climate and environmental factors may have influenced the unforeseen outcome.

In the first year of the experiment, the plots treated with dry + zeolite$^-$ + farmyard manure had the lowest plant height, while the plots treated with dry + zeolite$^+$ + farmyard manure showed higher plant height (Figure 3). In the second year of the experiment, the plots irrigated and treated with zeolite had a higher plant height than those only irrigated and treated traditionally. However, the plots irrigated and treated with zeolite had the lowest plant height overall.The diagram is shown in Figure 4. For this reason, the interaction between nitrogen applications, zeolite applications, and growing conditions may have been of considerable importance. During the first year of the experiment, the plots treated with dry, zeolite$^-$, and chemicals had the shortest first pod height. In contrast, the plots treated with irrigation, zeolite, and chemicals had the tallest first pod height (Figure 4). The irrigated + zeolite$^-$ + chemical plots had the lowest first pod height, whereas the irrigated + zeolite$^+$ + chemical plots had a greater first pod height in the second year of the experiment (Figure 5). For this reason, the interaction between nitrogen applications, zeolite applications, and growing conditions may have been significant.

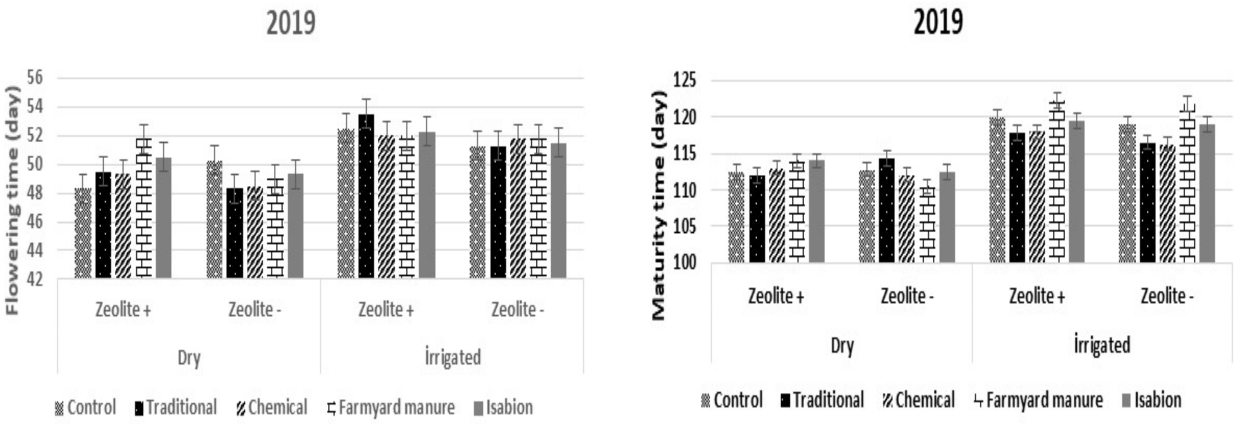

Figure 2. The interaction between growing conditions, zeolite applications and nitrogen applications for flowering and maturity time of chickpea.

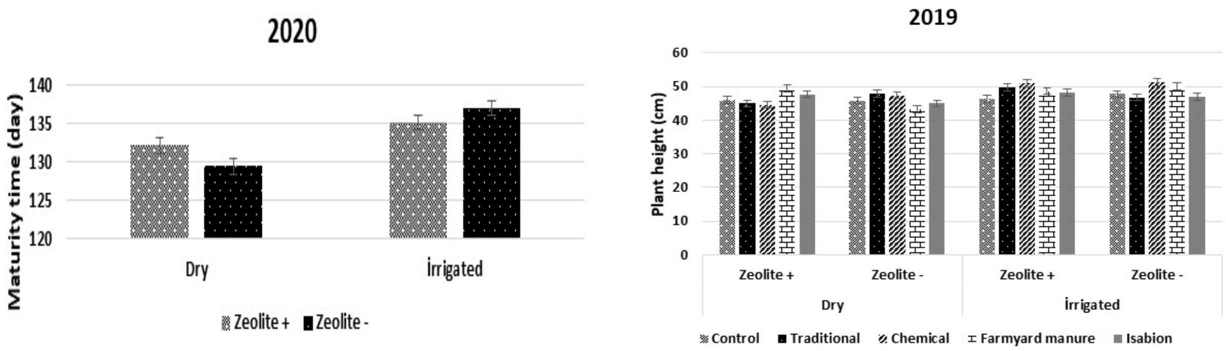

Figure 3. The interaction between growing conditions and zeolite applications for maturity time (2020); the interaction between growing conditions, zeolite applications and nitrogen applications (2019) for plant height of chickpea.

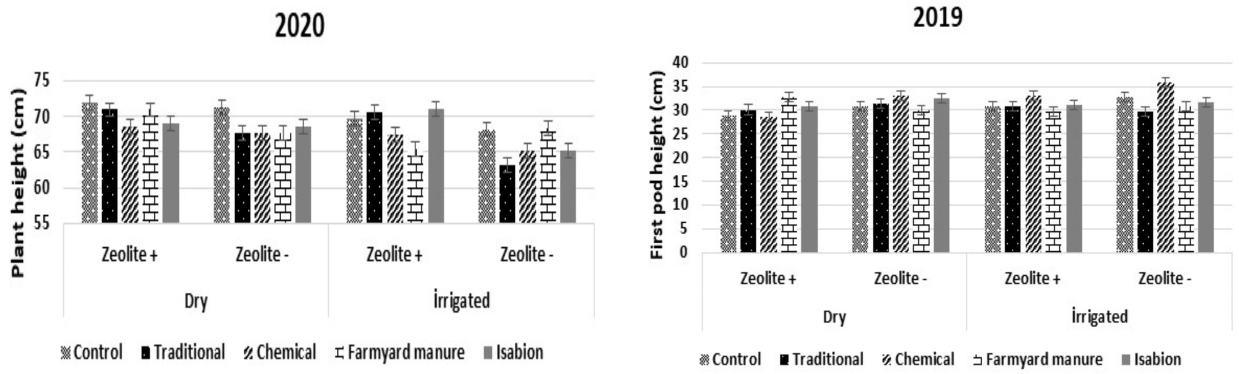

Figure 4. The interaction between growing conditions, zeolite applications and nitrogen applications for plant height (2020); the interaction between growing conditions, zeolite applications and nitrogen applications (2019) for first pod height of chickpea.

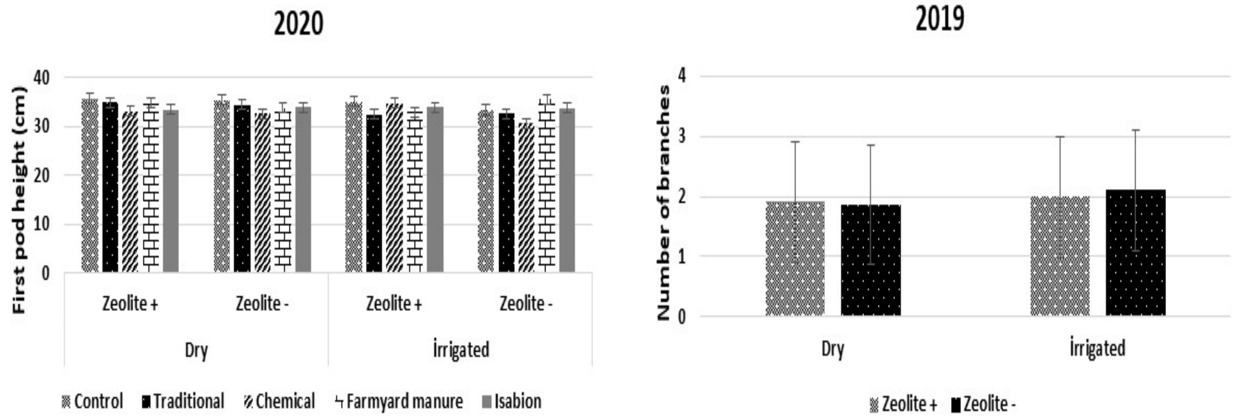

Figure 5. The interaction between growing conditions, zeolite applications and nitrogen applications for first pod height (2020); the interaction between growing conditions and zeolite applications (2019) for number of branches of chickpea.

Number of Branches, Branch Diameter

In the first year, growing conditions were significant for the number of branches and branch diameter, but only branch diameter was significant for the second year (Table 4,5). The number of branches is higher in irrigated plots than in dry plots in the first year. Togay et al. (2005) found that the number of branches increased with irrigation in chickpeas. The impact of growing conditions was negligible due to considerable precipitation during the second year of the experiment. Yolcu (2008) found no disparity in the number of branches between control and irrigated plots in chickpeas. In the first and second years, the branch diameter is greater in irrigated plots compared to dry plots. The experiment demonstrated that irrigation of had a beneficial impact on the diameter of the branches. Although zeolite applications had little impact on the number of branches and branch diameter in the first year, these characteristics became substantial in the second year (Table 4,5). In the second year, the zeolite application plots exhibit more branches and larger branch heights. Zahedi et al. (2009) found that applying zeolite positively impacted the number of branches in their study. Chemical fertilizer plots yielded the highest number of branches in the first year, while traditional fertilizer plots yielded the highest value in the second year (Table 4,5). The number of branches in the control plots was the lowest during the first and second years of the experiment. The nitrogen applications increased the number of branches. The application of nitrogen in chickpeas increased the number of branches (Doğan, 2019; Demir, 2021). The farmyard manure plots produced the largest branch diameter in both years, perhaps because they included more organic matter.

In the first year, irrigated + zeolite$^-$ plots showed the highest value, while dry + zeolite$^-$ plots yielded the lowest number of branches. The lowest and maximum number of branches were obtained from zeolite$^-$ plots, indicating the importance of the relationship of the growing conditions x zeolite applications. (Figure 5). The dry + Isabion plots produced the fewest branches in the first year, whereas the irrigated + Isabion plots displayed the highest value. The Isabion plots yielded the lowest and largest number of branches, indicating the importance of the interaction of growth conditions x nitrogen applications (Figure 6). The irrigated + zeolite$^+$ + chemical plots produced the fewest branches, but other chemical applications yielded higher numbers in the second year. Thus, it's possible that the relationship between the growth conditions, zeolite applications, and nitrogen applications was significant (Figure 6). The irrigated + zeolite$^+$ plots showed the highest value in the first year, while the dry + zeolite$^+$ plots produced the lowest branch diameter. While zeolite application negatively affected the branch diameter in dry plots, zeolite application increased the branch diameter in irrigated plots. As a result, it was discovered that the relationship between growing conditions and zeolite applications was significant (Figure 7). Irrigated plots yielded larger branch diameters for every nitrogen application in the first year than dry plots, which yielded lower branch diameters. Thus, it's possible that the relationship between the nitrogen applications and the growing applications was significant (Figure 7). The zeolite$^+$ + farmyard manure plots showed the highest value in the first year, while the zeolite$^+$ + traditional plots produced the lowest branch diameters. Thus, it's possible that the relationship between nitrogen applications and zeolite applications was significant (Figure 8). The lowest branch diameter was produced by irrigation + zeolite$^+$ + Isabion plots; in contrast, other Isabion applications showed a larger value in the second year. Thus, it's possible that the relationship between the growth conditions, zeolite applications, and nitrogen applications was significant (Figure 8).

Grain Yield

Growing conditions significantly impacted grain yield in the first and second years. (Table 4,5). The grain yield was greater in irrigated conditions than in dry conditions in both years. The grain yield of chickpeas is greatly affected by environmental factors. Chickpea exhibits a high tolerance to drought conditions, yet, it also demonstrates a favorable response to irrigation (Ceyhan et al. 2012; Kahraman et al., 2016; Arif et al., 2021).

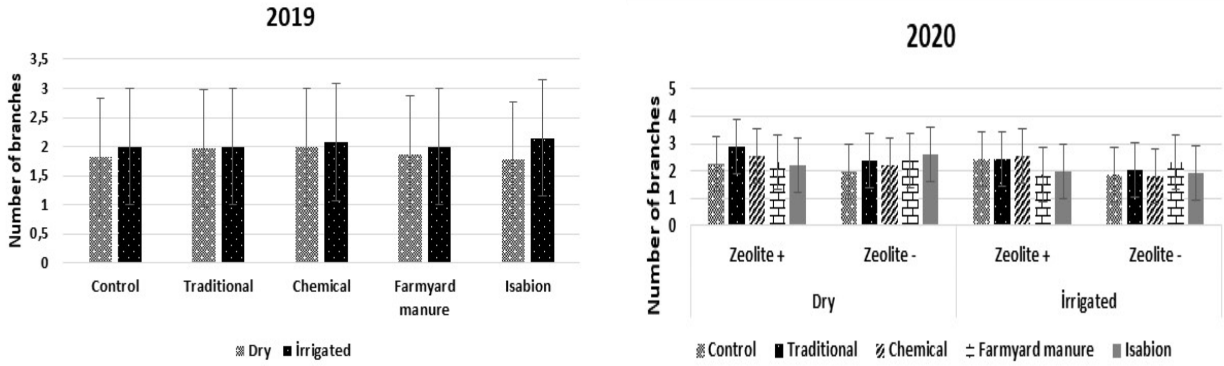

Figure 6. The interaction between growing conditions and nitrogen applications for number of branches (2019); the interaction between growing conditions, zeolite applications and nitrogen applications (2020) for number of branches of chickpea.

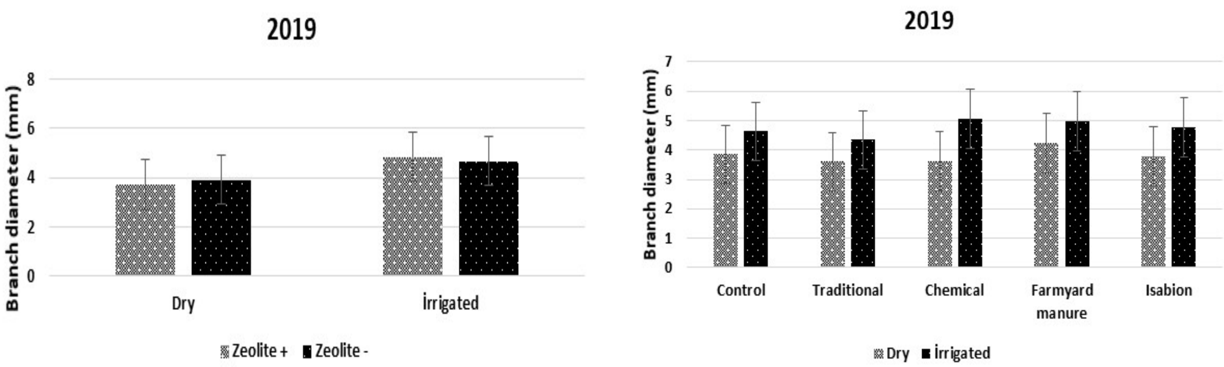

Figure 7. The interaction between growing conditions and zeolite applications for branches diameter (2019); the interaction between growing conditions and nitrogen applications (2019) for branches diameter of chickpea.

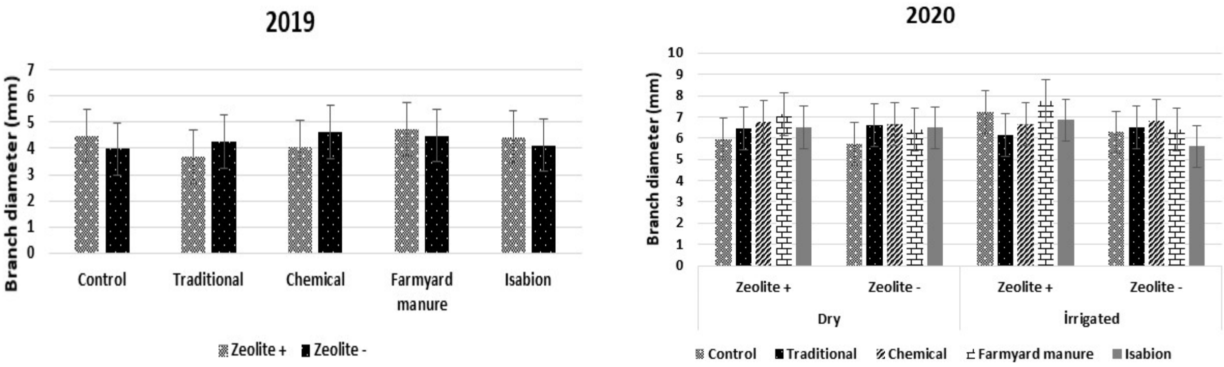

Figure 8. The interaction between zeolite applications and nitrogen applications for branches diameter (2019); the interaction between growing conditions, zeolite applications and nitrogen applications (2020) for branches diameter of chickpea.

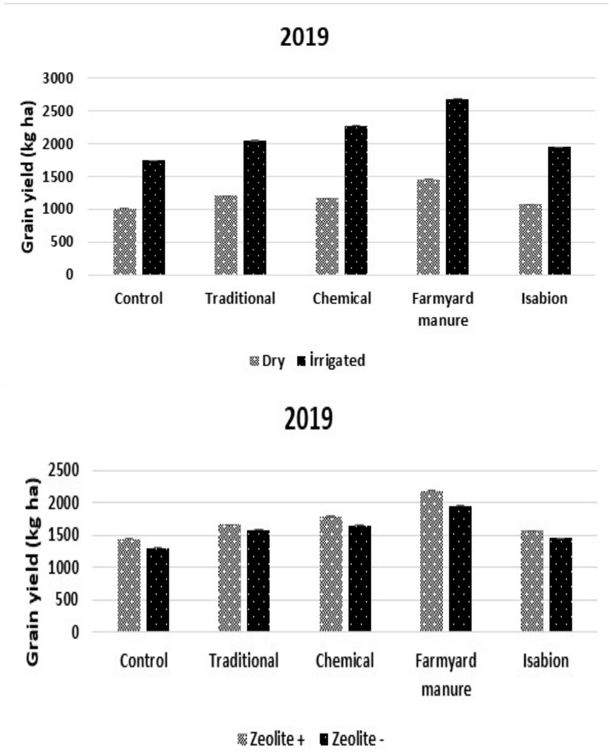

Figure 9. The interaction between growing conditions and nitrogen applications for grain yield (2019); the interaction between zeolite applications and nitrogen applications (2019) for grain yield of chickpea.

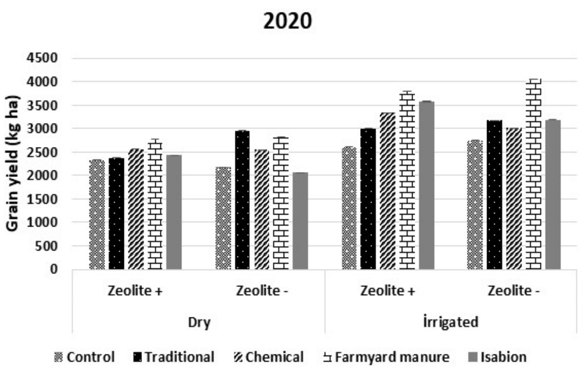

Figure 10. The interaction between growing conditions, zeolite applications and nitrogen applications for grain yield of chickpea.

In the first year, the irrigated plots produced 81% more grain compared to the dry plots, whereas in the second year, the irrigated plots yielded 29% more grain. In a study conducted by Muruiki et al. (2021), it was discovered that the application of irrigation resulted in a significant 60.3% increase in chickpea grain yield. In the first year, zeolite applications substantially impacted grain yield; however, they were insignificant in the second year (Table 4,5). The grain yield in the zeolite$^+$ treatment was measured at 1730 kg ha^{-1}, while in the zeolite$^-$ treatment it was 1590 kg ha^{-1} in the first year. Zeolite enhances plant growth by effectively retaining water and nutrients, limiting their loss through leaching. According to Mondal et al. (2021), zeolite enhances the ability of plants to withstand drought conditions in semi-arid locations. According to Amiri et al. (2021), using zeolite in soybeans resulted in a 64% increase in grain yield compared to the control plots. Applying zeolite resulted in increased grain yield during the first year, but no effect was observed in the second year. During the second year of the experiment, the presence of adequate rainfall and favorable climatic conditions made it impossible to assess the impact of the zeolite (Figure 1). In their study, Hoseini et al. (2020) found that the application of zeolite did not have any significant impact on the grain yield of chickpeas. The application of nitrogen had a notable effect on grain yield during the first and the second seasons, as indicated in Tables 4 and 5. The application of farmyard manure yielded the most favorable outcomes in both years, whereas the control plots exhibited the least satisfactory results regarding nitrogen applications.Farmyard Grain yield benefits from the presence of farmyard manure, which includes an abundance of organic matter and plant nutrients. According to Janmohammadi's (2018) research, the use of organic fertilizer for chickpeas resulted in a significant increase in crop output. According to Demir's (2021) findings, the plots treated with chicken dung produced the most significant amount of grain, while the control plots produced the lowest amount.

In the first year, nitrogen applications in dry regions resulted in low values, but irrigated regions exhibited large grain yields. Therefore, the interaction of growing conditions x nitrogen applications may have been significant. farmyard manure + irrigated plots gave the best results (Figure 9). Zeolite$^+$ plots achieved high grain yields, whereas zeolite$^-$ plots produced poor values for all nitrogen applications in the first year. Therefore, the interaction between zeolite applications x nitrogen applications may have been significant. Farmyard manure + zeolite$^+$ plots gave the best results (Figure 9). While the highest grain yield was obtained in irrigated + zeolite$^-$ + farmyard manure plots, dry + zeolite$^-$ + Isabion manure plots showed lowest grain yields in the second year of the experiment (Figure 10). The grain yield was more significant in the traditional and farmyard manure plots than in the plotswhere zeolite was not used, specifically during the second year of the experiment when the growth conditions were dry. The zeolite's water adsorption capacity may have been compromised in the second year of the experiment due to significant precipitation (Figure 1). Under arid growth conditions, Isabion had a more favorable response to zeolite. The grain yield was more significant in plots treated with zeolite$^+$ than plots treated with zeolite$^-$ under dry conditions at the Isabion plots.

Conclusions

The experiment found that irrigation caused a delay in phenological characteristics, but had a favorable impact on morphological characteristics and yield. A surplus of rainfall was recorded in the second year, particularly in June. The abundant rainfall hindered our results to observe the impact of irrigation on the studied traits. The effect of zeolite applications were different in the first and second years of the experiments for the investigated characters. Zeolite application had a positive impact on grain yield in the first year but had no impact in the second year. During the second year of the experiment, the presence of adequate rainfall and favorable climatic circumstances made it impossible to determine the impact of the zeolite. The experiment demonstrated that chemical fertilizer and farmyard manure had a good impact on the phenological and morphological traits. The farmyard manure plots gave the highest yield values of grains in both years. Farmers in Turkiye should apply nitrogen to their crops due to the recent rise in their earnings from chickpeas. Farmers have the option of substituting chemical fertilizers when the exorbitant cost of farm manure prevents its use.

Declarations

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