Turkish Journal of Agriculture - Food Science and Technology, 12(s3): 2699-2703, 2024
DOI: https://doi.org/10.24925/turjaf.v12is3.2699-2703.7174

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

The Effect of Weed Control at Different Periods on Antioxidant Content of Faba Bean (*Vicia faba* L.)

Bahadir Şin[1,a,*], Melike Köse[2,b], Mustafa Yılmaz[2,c]

[1]*Sakarya University of Applied Sciences, Faculty of Agriculture, Department of Plant Protection, Sakarya, Türkiye*
[2]*Sakarya University of Applied Sciences, Faculty of Agriculture, Department of Field Crops, Sakarya, Türkiye*
[*]*Corresponding author*

ARTICLE INFO

Research Article

Received : 05.10.2024
Accepted : 19.11.2024

Keywords:
Faba bean
Weed control
Yield
DPPH
Sakarya

ABSTRACT

Faba bean (*Vicia faba* L.) is a significant member of the Fabaceae family, known for its high protein content and rich phenolic compounds essential for human nutrition. These phenolic compounds, which belong to the group of secondary metabolites, serve as important dietary components. Secondary metabolites, act as plant defence mechanisms and can fluctuate under stress conditions. Weeds negatively impact the growth of cultivated plants by competing for nutrients and creating a stressful environment. This study evaluated the effects of weeds on the yield and quality parameters of faba bean. Conducted in Sakarya, the research aimed to determine how weed control frequency affects the yield and some secondary metabolites of faba bean. The experiment used a randomized block design with four replications and included four faba bean genotypes: two registered varieties (Eresen-87 and Salkım) and two local populations (Bilecik and Sakarya). Weed control treatments; comprised weedy control, hoeing every 15 days, and hoeing every 30 days. Measured parameters included plant height (cm), number of pods per plant, number of seeds per pod, 1000 seed weight (g), dry seed yield (g), and DPPH radical scavenging activity (%). Data were analyzed using Duncan's Multiple Range Test with SPSS, revealing statistically significant differences ($p<0.05$) in all measured parameters. The tallest plants were found in the Salkım×Control plot, while the shortest were in Sakarya×15. The highest number of pods occurred in Sakarya×30, and the lowest in Eresen-87×15. The highest number of seeds per pod was recorded in Bilecik×15, while the lowest was in all treatments of the Salkım variety and the Eresen-87×15 plot. The highest dry seed yield came from Bilecik×15, with the lowest from Eresen-87×30. DPPH activity peaked in Bilecik×Control, indicating significant differences in yield and nutritional content among faba bean genotypes. These findings indicate that different genotypes excel in various agricultural and nutritional characteristics, demonstrating that these differences can play an important role in shaping future production strategies.

[a] *sinbahadir@gmail.com* *https://orcid.org/0000-0002-0109-3662*
[b] *melikek@subu.edu.tr* *https://orcid.org/0000-0001-5061-2441*
[c] *mustafayilmaz@subu.edu.tr* *https://orcid.org/0000-0001-5256-245X*

Introduction

Initially domesticated in the Fertile Crescent around 9000–10,000 BC, its cultivation spread over time through Anatolia to Europe and across the Mediterranean. By ancient times, it had become a staple in agricultural systems in regions such as Iraq, Iran, and Syria, supporting early societies with its high protein content and resilience. Throughout history, the faba bean maintained its status as a vital food source in the Middle East, Mediterranean, and Asia. Today, it continues to be widely grown in these areas, underscoring its enduring role in global agriculture (Fouad et al., 2013). Faba bean is nutritionally important due to its high protein content (22-36%), rich amino acid profile, and high levels of various vitamins and minerals. Additionally, its ability to fix nitrogen (130-160 N kg ha^{-1}) contributes to soil fertility, playing a crucial role in crop rotation. This characteristic highlights the faba bean in sustainable agricultural practices (Bond et al., 1985; Duc, 1997; Singh et al., 2013).

Faba beans are commonly used as fresh vegetables, dried seed on the human diet, and animal feed. Additionally, the plant is a natural source of important biological compounds like levodopa (L-dopa). L-dopa, a substance used in the treatment of Parkinson's disease, improves motor functions by increasing dopamine production in nerve cells. Thus, the faba bean is considered a valuable plant in the food and pharmaceutical industries (Nagatsu & Sawada, 2009; Crépon et al., 2010).

The agricultural production of faba beans can be carried out across a wide range of climatic conditions. Its tolerance to cold climates and adaptability to different soil types enable the growth of faba beans in various regions of the world (Ertoy İnci & Toker, 2011; Arya et al., 2024). Faba beans can be grown using both local populations and registered cultivars. Each genotype offers different advantages in agricultural production. Local populations are genotypes that have adapted to specific regions over many years through natural selection and traditional farming methods. These populations generally exhibit resistance to environmental stresses and genetic diversity, although they may demonstrate variability in terms of yield and quality. On the other hand, registered cultivars are specifically bred for high yield and quality. While they are preferred in commercial farming for their stable yield and quality, local populations play a crucial role in preserving genetic diversity and promoting sustainable agriculture (Bayrak & Önder, 2017; Karaköy et al., 2017; Kan et al., 2019).

Faba beans are exposed to various biotic and abiotic stress factors during their growth period. One of the biotic stress factors is the presence of weeds, which compete for resources such as nutrients, water, and light, negatively affecting the plant's productivity. In the faba bean cultivation fields, various weed species have been encountered, including corn poppy (*Papaver rhoeas* L.), dill (*Anethum graveolens* L.), field bindweed (*Convolvulus arvensis* L.), Italian ryegrass (*Lolium multiflorum* Lam.), prickly lettuce (*Lactuca serriola* L.), prostrate knotweed (*Polygonum aviculare* L.), round-leaved fluellen (*Kickxia spuria* (L.) Dumort.), scarlet pimpernel (*Anagallis arvensis* L.), stinking goosefoot (*Chenopodium vulvaria* L.), and wild mustard (*Sinapis arvensis* L.), among other notable weeds (Frenda et al., 2013). This competitive pressure can result in reduced yield parameters such as plant height, pod number, seed yield, and 1000 seed weight (Villegas-Fernández et al., 2024). Consequently, although registered cultivars generally exhibit higher yields than local populations, they often have lower phenolic content, highlighting a trade-off between productivity and nutritional quality.

Weed control is critical for increasing agricultural productivity and protecting plant health. However, the methods used during weed control and their application frequency can significantly affect both yield and biochemical compounds in plants (Gökalp & Üremiş, 2015). Due to the lack of licensed herbicides specifically approved for use in faba bean cultivation, weed control is primarily performed through mechanical means such as hoeing. This method of weed management can influence various plant physiological processes and stress responses. Leguminous plants, such as faba beans, produce biochemical compounds known as secondary metabolites, which enhance the plant's defence mechanisms against environmental stress factors. These compounds enhance the agricultural value of faba beans and are also important for human health. Antioxidants, an important group of secondary metabolites, play a critical role in the defense mechanisms of plants against environmental stressors. The accumulation of free radicals and reactive oxygen species (ROS) in cells due to oxidative stress can vary depending on the biotic and abiotic stress factors the plant encounters (Isah, 2019). Oxidative stress damages cellular structures, leading to the degradation of proteins, lipids, and DNA, which can cause various diseases. To prevent this damage, plants produce antioxidant compounds that neutralize free radicals. The antioxidant capacity of phenolic compounds with antioxidant properties is determined by the DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging activity analysis using spectrophotometric methods. The high antioxidant capacity of faba beans has been confirmed through these analyses. In this context, the antioxidant capacity of phenolic compounds in plants like faba beans is of great importance, both for protecting plant health and benefiting human health as well (Rybiński et al., 2019; Shi et al., 2022). Information on the effects of weed control frequency on these compounds is limited, especially regarding biotic stress factors.

This study examines the effects of weed control frequency on certain yield and quality parameters of faba beans in Sakarya. The study aims to determine the responses of different genotypes to these effects. The results obtained should contribute to the development of weed control strategies in faba bean cultivation and to the selection of more productive varieties in terms of secondary metabolites. In this context, the study will provide an important resource for both increasing agricultural productivity and enhancing the nutritional content of faba beans.

Materials and Methods

The experiment was conducted in the application field of the Agricultural Sciences and Technologies Education Application and Research Center of Sakarya University of Applied Sciences.

Climatic Characteristics

According to Table 1, the temperatures in Sakarya province during the 2023-24 growing season were generally slightly higher than the long-term averages (LTA). This difference is particularly noticeable in April and June. When we examine the precipitation amounts, there was a significant increase in November and December compared to the long-term averages. However, in February and April, precipitation was lower. In June, the amount of rainfall significantly decreased compared to the LTA (3.0 mm). Relative humidity was generally close to the LTA, although it was slightly lower in April and June. This situation is consistent with the lower rainfall during these periods.

The analysis of the soil properties from the research field indicates that the soil has a loamy texture, is slightly alkaline, and is calcareous. The soil is non-saline, with low levels of phosphorus, potassium, and organic matter (Table 2).

Experimental Design and Treatments

Four faba bean genotypes were used as plant material: two registered varieties (Eresen-87 and Salkım) and two local populations (Bilecik and Sakarya) collected from different provinces. The experiment was established in a randomized block design with four replications, with a sowing norm of 50 cm between rows, 20 cm within rows, and a sowing depth of 6 cm.

Table 1. Climate data for the 2023-24 growing season in Sakarya

Months	Average Temperature (°C)		Total Precipitation (mm)		Average Relative Humidity (%)	
	2023-24	LTA	2023-24	LTA	2023-24	LTA
November	14.1	12.4	177.1	63.1	77.0	83.3
December	10.4	8.3	167.8	113.0	80.8	83.4
January	7.8	6.6	147.5	96.8	80.3	82.0
February	9.6	8.0	54.2	81.4	78.6	80.0
March	10.7	9.5	79.0	78.9	78.9	78.8
April	16.5	13.2	19.9	54.7	71.0	76.4
May	16.1	17.9	75.2	72.0	78.9	76.8
June	24.7	21.9	3.0	85.0	66.8	77.3

Sakarya Provincial Meteorology Directorate, LTA: Long Term Averages

Table 2. Soil properties of the research area

Soil Properties	Analysis Results	Classification
Soil Texture (%)	48.1	Loamy
pH	7.51	Slightly alkaline
Lime ($CaCO_3$ %)	3.98	Calcareous
Total Salt (%)	0.005	Non-saline
Phosphorus (P_2O_5 kg da^{-1})	0.057	Very low
Potassium (K_2O kg da^{-1})	18.51	Low
Organic Matter (%)	1.45	Low

Soil Characteristics

To determine the effects of weed control at different intervals on certain yield and quality elements, the genotypes were subjected to three different treatments: plots with no weed control, plots with weed control applied was performed every 15 days, and plots where weed control was performed every 30 days. After harvest, parameters such as plant height (cm), number of pods per plant (count), number of seeds per pod (count), 1000 seed weight (g), dry seed yield (g), and DPPH radical scavenging activity (%) were measured. Observations and measurements were taken according to the standards of the International Union for the Protection of New Varieties of Plants (UPOV, 2024). DPPH contents were determined using the method proposed by Faller and Fialho. To 0.1 ml of the ground and extracted sample, 3.9 ml of DPPH (TCI, Japan) solution prepared at a concentration of 0.1 mM in 80% methanol was added. The samples were covered with aluminum foil and kept in a light-proof environment for 30 minutes. Then, the absorbance values of the samples were measured at a wavelength of 517 nm using a spectrophotometer (Faller and Fialho, 2009). DPPH contents were calculated using the formula: "% Inhibition = [(Control absorbance – Extract absorbance) / Control absorbance] × 100." The obtained data were subjected to Duncan's Multiple Range Test using the SPSS statistical software package. The statistical analyses were conducted at a 5% confidence interval level.

Results and Discussion

The findings provide a detailed account of the responses of each parameter examined in the study to the various treatments applied. In this table, the varieties are presented along with their respective treatments. The entries labelled 'Genotype×Control' represent the plots where no weed control was applied, 'Genotype×15' indicates the plots where weed control was performed every 15 days, and 'Genotype×30' refers to the plots where weed control was applied every 30 days.

The data for plant height, number of pods per plant, number of seeds per pod, 1000 seed weight, dry seed yield, and DPPH content, which are among the parameters examined in the study, presented in Table 3.

According to Table 3, the tallest plant height was observed in the Salkım×Control genotype (114.0 cm). The shortest plant height was recorded in the Sakarya×15 genotype (98.4 cm). In terms of the number of pods, the Sakarya×30 genotype outperformed the others with 16.1 pods. In contrast, the lowest number of pods was found in the Eresen-87×15 genotype (9.3 pods). The highest number of seeds per pod was observed in the Bilecik×15 genotype (3.40 seeds). The lowest seed counts were recorded in the Salkım×Control (2.87 seeds), Salkım×30 (2.92 seeds), Eresen-87×15 (2.95 seeds), and Salkım×15 (2.97 seeds) genotypes. Compared to previous studies, Alan & Geren (2006) reported that faba bean plant heights ranged from 79.4 to 130.1 cm. In a study by Pekşen & Gülümser (2007) that examined yield parameters using local faba bean populations, lines, and varieties, the number of pods per plant was found to range between 10.70 and 18.38 pods. In another study that evaluated seed number per pod as one of the parameters, the range was reported to be 2.91 to 8.60 seeds per pod (Pekşen, 2006). When evaluating the data, we found that the results of our study were consistent with previous research.

The highest 1000-seed weight was observed in the Eresen-87×Control genotype (1.616 g), while the lowest values were found in the Bilecik×30 (1.097 g), Sakarya×30 (1.101 g), and Bilecik×15 (1.114 g) genotypes. Regarding dry seed yield, the Bilecik×15 genotype had the highest yield (564.0 kg da^{-1}), while the Eresen-87×30 genotype showed the lowest yield (244.7 kg da^{-1}). The DPPH value, which represents antioxidant activity, was the highest in the Bilecik×Control genotype (36.1%) and the lowest in the Sakarya×15 (31.1%) and Bilecik×15 (31.2%) genotypes. In a study evaluating weight of 100 seeds, it was reported to range between 144.4-213.9 g (Pekşen, 2007).

Table 3. Average values of parameters researched in the study

Genotype	Application	Plant Height (cm)	Number of Pods (per plant)	Number of Seeds (per pod)	1000 Seed Weight (g)	Dry Seed Yield (kg da^{-1})	DPPH (%)
Eresen-87	Weed	105.8^{abcd}	10.7^{cde}	3.05^{ab}	1.626^{a}	295.0^{efg}	33.6^{abc}
	15	107.5^{abc}	9.3^{e}	2.95^{b}	1.461^{b}	422.7^{bc}	33.0^{bc}
	30	109.3^{ab}	13.1^{b}	3.12^{ab}	1.339^{cd}	244.7^{g}	34.4^{ab}
	Average	107.5	11.0	3.04	1.475	333.0	33.7
Salkım	Weed	114.0^{a}	9.6^{cd}	2.87^{b}	1.406^{bc}	264.9^{fg}	33.4^{abc}
	15	104.6^{bcd}	11.5^{bcd}	2.97^{b}	1.314^{cd}	349.6^{de}	31.7^{bc}
	30	107.0^{abc}	10.0^{cde}	2.92^{b}	1.248^{de}	331.3^{def}	33.7^{abc}
	Average	108.5	10.4	2.92	1.323	315.0	32.9
Bilecik	Weed	106.3^{abcd}	11.6^{bc}	3.15^{ab}	1.194^{ef}	322.7^{def}	36.1^{a}
	15	106.4^{abcd}	12.7^{b}	3.40^{a}	1.114^{f}	564.0^{a}	31.2^{c}
	30	105.5^{bcd}	13.2^{b}	3.17^{ab}	1.097^{f}	440.9^{b}	31.7^{bc}
	Average	106.1	12.5	3.24	1.135	443.0	33.0
Sakarya	Weed	110.8^{ab}	11.3^{bcd}	3.20^{ab}	1.172^{ef}	336.0^{de}	31.5^{bc}
	15	98.4^{d}	11.9^{bc}	3.22^{ab}	1.198^{ef}	374.9^{cd}	31.1^{c}
	30	100.4^{cd}	16.1^{a}	3.20^{ab}	1.101^{f}	319.7^{def}	32.3^{bc}
	Average	103.2	13.1	3.21	1.157	344.0	31.6
Overall Average		106.3	11.7	3.10	1.272	358.6	32.8

$p<0.05$

In another study examining the yield elements of different genotypes, dry seed yield was found to range between 221.7-479.0 kg da^{-1}. Saini et al. (2016) reported that DPPH content ranged from 22.8% to 73.5% in a study investigating antioxidant activity in dry seeds. When evaluating the relevant data, the results of our study are similar in terms of 1000-seed weight and are consistent in dry seed yield, except for the Bilecik×15 plot, which showed the highest yield. The increase in yield in plots where hoeing was performed every 15 days is also notable. When comparing DPPH content, the results of our study are in harmony with those of previous studies.

In a general assessment, these results reveal significant differences between the genotypes in terms of plant height, pod number, and seed number per pod. The Sakarya×30 genotype stands out in terms of pod number, while the Salkım×Control genotype showed the highest value in plant height. The Bilecik×15 genotype had the highest number of seeds per pod. The Eresen-87×Control genotype stood out in terms of 1000-seed weight, while the Bilecik×15 genotype, despite not having the highest values for dry seed yield or antioxidant activity, showed satisfactory results. On the other hand, the Bilecik×Control genotype attracted attention with the highest DPPH value in terms of antioxidant activity. These findings could help shape future production strategies by highlighting the superior agricultural and nutritional traits of different genotypes.

Conclusion

This study has revealed significant differences in the agricultural performance and nutritional content of different faba bean genotypes. While the Sakarya×30 genotype showed superior performance in terms of pod number, the Salkım×Control genotype recorded the highest value in terms of plant height. The highest seed number per pod was observed in the Bilecik×15 genotype. The Eresen-87×Control genotype stood out in terms of 1000 seed weight, whereas the Bilecik×15 genotype presented satisfactory results in critical parameters such as dry seed yield and antioxidant activity. Particularly, the Bilecik×Control genotype drew attention with its high DPPH value, reflecting its strong antioxidant activity. These findings emphasize the superior agricultural and nutritional traits of various genotypes and suggest that these genotypes could play a crucial role in shaping future production strategies.

Declarations

This study was supported by Sakarya University of Applied Sciences Scientific Research Projects Commission under the grant no: 171-2023.

This paper was presented in III. International (XV. National) Field Crops Congress.

References

Alan, Ö. & Geren, H. (2006). Ödemiş-İzmir koşullarında yetiştirilen bazı bakla (*Vicia faba* var. major) Çeşitlerinin tohum verimi ve diğer bazı özellikleri üzerinde bir araştırma. *Ege Üniversitesi Ziraat Fakültesi Dergisi, 43*(1), 13-20. ISSN 1018-8851.

Arya, R. K., Dahiya, G. S., Kumar, R., Gill, R. K., Tiwari, J. K., Yadav, C. B., & Kant, S. (2024). Development of novel faba bean (*Vicia faba* L.) for release as a new cultivar with high yield and protein content. *Genetic Resources and Crop Evolution, 71*(6), 2831-2842. https://doi.org/10.1007/s10722-023-01807-1.

Bayrak, H., & Önder, M. (2017). Konya ekolojisi'nde tarımı yapılan yerel nohut popülasyonları ve çeşitlerinin (*Cicer arietinum* L.) tarımsal, teknolojik ve besinsel karakterlerinin belirlenmesi. *Tarla Bitkileri Merkez Araştırma Enstitüsü Dergisi*, *26*, 52-61. https://doi.org/10.21566/tarbitderg.359119.

Bond, D. A., Lawes, D. A., Hawtin, G. C., Saxena, M. C., & Stephens, J. S. (1985). In R. J. Summerfield, & E. H. Roberts (Eds.), *Faba Bean* (*Vicia faba* L.). Grain Legume Crops. (pp. 199−265) 8 Grafton Street, London, WIX 3LA, UK: William Collins Sons Co. Ltd.

Crépon, K., Marget, P., Peyronnet, C., Carrouée, B., Arese, P., & Duc, G. (2010). Nutritional value of faba bean (*Vicia faba* L.) seeds for feed and food. *Field Crops Research, 115*(3), 329-339. https://doi.org/10.1016/j.fcr.2009.09.016.

Duc, G. (1997). Faba bean (*Vicia faba* L.). *Field Crops Research, 53*(1-3), 99-109.

Ertoy İnci, N., & Toker, C. (2011). Screening and selection of faba beans (*Vicia faba* L.) for cold tolerance and comparison to wild relatives. *Genetic Resources and Crop Evolution*, *58,* 1169-1175. https://doi.org/10.1007/s10722-010-9649-2.

Isah, T. (2019). Stress and defense responses in plant secondary metabolites production. *Biological research*, *52*. https://doi.org/10.1186/s40659-019-0246-3.

Faller, A. L. K., & Fialho, E. (2009). The antioxidant capacity and polyphenol content of organic and conventional retail vegetables after domestic cooking. *Food Research International, 42*(1), 210-215. https://doi.org/10.1016/j.foodres.2008.10.009.

Frenda, A. S., Ruisi, P., Saia, S., Frangipane, B., Di Miceli, G., Amato, G., & Giambalvo, D. (2013). The critical period of weed control in faba bean and chickpea in Mediterranean areas. *Weed Science*, 61(3), 452-459. https://doi.org/10.1016/B978-0-12-397935-3.00005-0.

Fouad, M., Mohammed, N., Aladdin, H., Ahmed, A., Xuxiao, Z., Shiying, B., & Tao, Y. (2013). *Faba bean*. Genetic and Genomic Resources of Grain Legume Improvement. 113-136.

Gökalp, Ö. & Üremiş, İ. (2015). Mardin'de buğday ürününe karışan yabancı ot tohumlarının belirlenmesi. *Mustafa Kemal Üniversitesi Ziraat Fakültesi Dergisi, 20*(1):23-30. ISSN: 1300-9362.

Kan, M., Sözen, Ö., Kan, A., Karadavut, U., & Yağmur, M. (2019). Orta Kızılırmak Vadisi'nde üretici şartlarında yerel kuru fasulye popülasyonlarının doğal kaynak ekonomisi açısından genel değerlendirilmesi. *Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi*, *22*(3), 389-398. https://doi.org/10.18016/ksutarimdoga.vi.500621.

Karaköy, T., Demirbaş, A., Toklu, F., Karagöl, E. T., Uncuer, D., Gürsoy, N., & Özkan, H. (2017). Ülkemizin farklı bölgelerinden toplanan bakla (*Vicia faba* L.) yerel popülasyonlarının agronomik ve morfolojik karekterizasyonu. *KSÜ Doğa Bilimleri Dergisi*, *20*, 356-361. https://doi.org/10.18016/ksudobil.349299.

Nagatsu, T., & Sawada, M. (2009). L-dopa therapy for Parkinson's disease: past, present, and future. *Parkinsonism & Related Disorders, 15*, 3-8. https://doi.org/10.1016/S1353-8020(09)70004-5.

Pekşen, E. & Artık, C. (2006). Bazı yöresel bakla (*Vicia faba* L.) populasyonlarının bitkisel özellikleri ve tane verimlerinin belirlenmesi. *Journal of Agricultural Sciences, 12*(2), 270-277. https://doi.org/10.1501/Tarimbil_0000000479.

Pekşen, E. & Gülümser, A. (2007). Sonbahar ve ilkbaharda ekilen bakla (*Vicia faba* L.) genotiplerinin bazı bitkisel özellikler ve tane verimi bakımından karşılaştırılması. *Anadolu Tarım Bilimleri Dergisi, 22*(1), 79-85.

Pekşen, E. (2007). Bakla (*Vicia faba* L.)'da özellikler arasındaki ilişkiler ve tane verimi bakımından seleksiyon kriterlerinin belirlenmesi. *Anadolu Tarım Bilimleri Dergisi, 22*(1), 73-78.

Rybiński, W., Karamać, M., Sulewska, K., & Amarowicz, R. (2019). Antioxidant activity of faba bean extracts. *Plant Extracts*. IntechOpen. https://doi.org/10.5772/intechopen.85534.

Saini, P., Singh, P., Dubey, S., & Srivastava, A. (2016). Effect of different processing methods on polyphenolic content and antioxidant activity of broad beans (*Vicia faba* L.). *International Journal of Current Research and Review*, *8*(13), 6.

Shi, S. H., Lee, S. S., Zhu, Y. M., Jin, Z. Q., Wu, F. B., & Qiu, C. W. (2022). Comparative metabolomic profiling reveals key secondary metabolites associated with high quality and nutritional value in broad bean (*Vicia faba* L.). *Molecules*, *27*(24), 8995. https://doi.org/10.3390/molecules27248995.

Singh, A. K., Bharati, R. C., Manibhushan, N. C., & Pedpati, A. (2013). An assessment of faba bean (*Vicia faba* L.) current status and future prospect. *African Journal of Agricultural Research, 8*(50), 6634-6641. https://doi.org/10.5897/AJAR2013.7335.

UPOV (International Union for The Protection of New Varieties of Plants), (2024). Guidelines for the Conduct of Tests for Distinctness, Uniformity and Stability. https://www.upov.int/edocs/mdocs/upov/en/twa_46/tg_8_7_proj_3.pdf. (Access date: 02.09.2024).

Villegas-Fernández, Á. M., Amarna, A. A., Moral, J., & Rubiales, D. (2024). Intercropping as a strategy for weed management in faba bean (*Vicia faba* L.). *Agronomy, 14*(6), 1170. https://doi.org/10.3390/agronomy14061170.