RESEARCH ARTICLE Legume Research- An International Journal, Volume 48 Issue 4: 623-632 (April 2025)

Using Zeolite and Nitrogen Applications in Different Growing Conditions for the Improvement Yield in Chickpea (*Cicer arietinum* L.)

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10.18805/LRF-835

ABSTRACT

Background: The present study investigated the effects of two different zeolite applications and different nitrogen-based fertilizers on the yield and yield components of chickpea in dry and irrigated conditions.

Methods: 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 split split plot with four replicates. The main plots included growing conditions (dry - irrigated); subplots included zeolite applications (zeolite$^+$ - zeolite$^-$); and sub-sub plots included nitrogen applications [control, traditional, chemical, barnyard manure and Isabion (an animal collagen-derived biostimulant)].

Result: All the investigated characters were higher in irrigated growing conditions than in dry growing conditions, except for protein content. Average rainfall was recorded throughout the first year of the experiment and the application of zeolite had a beneficial impact on both yield and yield components. Nevertheless, in the second year of the experiment, the application of zeolite was rendered ineffective due to an abundance of precipitation. Barnyard manure increased yield and yield components more than other nitrogen applications.

Key words: Biostimulant, Chickpea, Dry, Irrigated, Nitrogen, Zeolite.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) also known as gram, Bengal gram, Egyptian pea, garbanzo, garbanzo bean and chana (Singh and Dhkal, 2024). A significant source of protein, chickpeas are extensively used in certain countries due to the inadequacy of protein supply from animal sources. It plays a significant role in the reduction of fallow areas and is incorporated into the crop rotation in arid regions where winter grain-fallow rotation is the norm.

In agriculture practices, fertilizer is an important input to increase crop yields (Ashraf *et al*., 2024). In agricultural regions, the absence of plant nutrients is a prevalent issue. In order to resolve this issue, producers typically implement chemical fertilizers. Nevertheless, the unintentional and prolonged use of chemical fertilizers results in environmental pollution and a decline in soil health. In order to accomplish sustainable agriculture, it is necessary to reduce the unconscious use of chemical fertilizers, ensure that fertilization is cost-effective and regulate the soil structure while increasing plant productivity.

Calcite, gypsum and zeolite are among the inorganic soil amendments that have been extensively employed to improve agricultural production and mitigate environmental contamination. These items are additionally inexpensive (Rahimi *et al*., 2021; Fang *et al*., 2021; Turan, 2021). The highly porous structure of zeolites enables them to retain up to 60% of their own weight in water (Kocakusak *et al*., 2001). Zeolite can be employed to improve water infiltration and retention in arid regions. Furthermore, zeolites possess the ability to adsorb NH_4^+, which serves to mitigate their losses. Zeolites were able to regulate the release of NH_4^+ and K^+ over an extended period, resulting in a 65% and 74% reduction in leaching losses, respectively (Eslami *et al.,* 2017).

Barnyard manures are the most widely recognized and frequently employed organic fertilizers. The primary sources of nitrogen, phosphorus and sulfur required for plant nutrition are organic substances in the soil. The physical, chemical and biological properties of the soil are all positively impacted by soil organic matter, which also enhances the soil's water capacity, temperature and pH. Particularly in regions with intensive agriculture, the fertility of the soil can be enhanced by the application of organic fertilizers from a variety of sources.

Plant biostimulants are any substance or microorganism that is applied to plants to enhance the nutritional efficacy, abiotic stress tolerance and quality characteristics of the crop. In modest quantities, biostimulants can mitigate

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How to cite this article: Takil, E. and Kayan, N. (2025). Using Zeolite and Nitrogen Applications in Different Growing Conditions for the Improvement Yield in Chickpea (*Cicer arietinum* L.). Legume Research. 48(4): 623-632. doi: 10.18805/LRF-835.

Submitted: 19-09-2024 **Accepted:** 31-12-2024 **Online:** 31-01-2025

abiotic stress damage and reduce nutrient deficiencies (Bulgari *et al*., 2019; Kauffman *et al*., 2007).

One of the most important factors determining grain yield in plant growth is moisture stress (Halagalimath and Rajkumara, 2018). Chickpeas are typically cultivated without irrigation in Eskisehir province as a result of its semi-arid climate. The significance of soil amendments that absorb water, such as zeolite, has been underscored by recent observations of global climate change. Furthermore, the advantages of zeolite are enhanced when combined with various nitrogen sources. The objective of this study is to ascertain the impact of five distinct nitrogen-based fertilizers and two distinct zeolite applications on the yield and yield components of chickpeas in both arid and irrigated conditions.

MATERIALS AND METHODS

The field experiment was conducted at the experimental area of the Faculty of Agriculture, Eskisehir Osmangazi University, Eskisehir, Türkiye, between 2019 and 2020. Fig 1 displays climatic data pertaining to the research area. The cumulative precipitation was approximately consistent with historical averages in both years, but, there were variations in the monthly distribution of precipitation. In June, the cumulative rainfall exceeded 2.5 times the total rainfall recorded in the second year of the experiment. Consequently, the plants had significant benefits from the June rainfall in the second year. Soil analysis results of the research areas are shown in Table 1. During the first year, the soil sample exhibited a slightly alkaline pH, a very low organic matter content, a moderate level of calcium carbonate, absence of salt, a low nitrogen concentration, a high potassium concentration and a low phosphorus concentration. The soil composition in dry places is clay loam, while in irrigated areas it is loamy (Anonymous, 2019). In the second year, the soil sample exhibits a slightly alkaline pH, a very low organic matter content, a moderate level of calcium carbonate, absence of salt, low nitrogen levels, high potassium levels and sufficient phosphorus levels. In arid regions, the soil composition is predominantly loamy, but in areas with irrigation, it tends to be clay-loam (Anonymous, 2020).

The experimental design was split split plot with four replicates. The main plots were grown under dry and irrigated conditions; subplots received zeolite applications (zeolite^{+} and zeolite^{-}); and sub-sub plots received nitrogen applications control, traditional, chemical, barnyard 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 Gordes (Enli Mining Company). Diammonium phosphate (DAP) (18N-46%P) was used as traditional fertilizer and ammonium sulfate (AS) (21% N) + triple superphosphate (TSP) (44% P_2O_5) were used as chemical fertilizers. The barnyard manure was sourced from the Mahmudiye area of the Eskisehir province, while the Isabion was acquired from the Syngenta Company. Table 2 presents the physical and chemical characteristics of zeolite, Isabion and barnyard manure.

Sowing was done at a 30 cm row spacing at a seeding rate of 60 seeds m^{-2} on April 26 and 15, 2019 and 2020, respectively. The seeds were sprayed to prevent root rot and anthracnose diseases before sowing. Application times and ratios of the materials used in the experiment are given

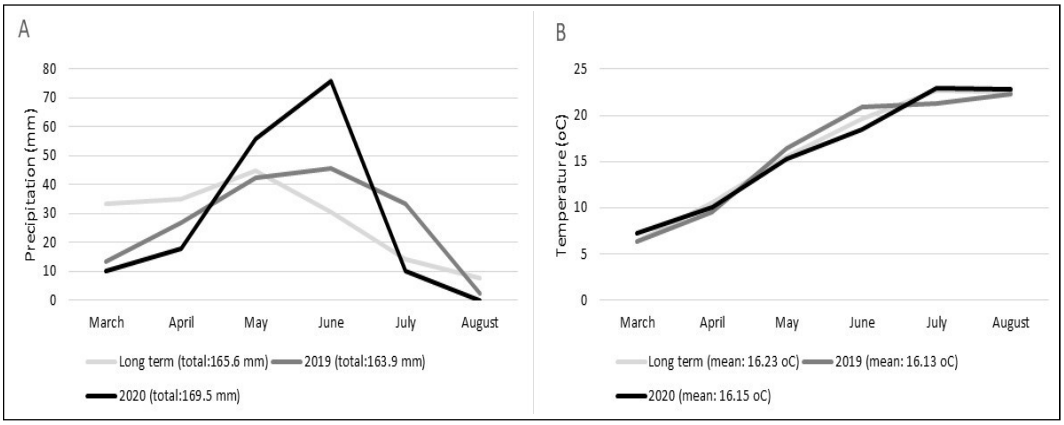


Fig 1: Climatic data of research area.

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 barnyard manure.

Properties	Zeolite	Isabion	Barnyard 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

in Table 3. Under irrigated conditions, plants were irrigated at emergence time, before flowering, flowering period, pod formation period and grain filling period. Weed control was done with herbicides. Spraying was done twice for anthracnose at the at the end of June and July. The harvest was done by hand in the first year, on August 26, 2019 and on August 23, 2020, in the second year.

Seed number per plant and grain yield per plant (g) were evaluated on 10 randomly selected plants in each sub-subplot. Each sub-subplot was harvested, blended and biological yield (kg ha^{-1}), and grain yield (kg ha^{-1}) were estimated (Tosun and Eser, 1978). The microKjeldahl method was used to determine the seed nitrogen content, which was multiplied by 6.25 to determine the seed protein content (%) (Nelson and Sommers, 1973).

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

Results and Discussion

Seed number per plant

In the first and second years, growing conditions and nitrogen applications had a significant impact on seed number per plant. Zeolite applications were significant in the first year but insignificant in the second year (Table 4, 5). In both years, the seed number per plant was higher in irrigated conditions than in dry conditions. Samarah *et al*. (2009) and Kayan (2012) reported that the number of seeds per plant in chickpeas rose when irrigation was applied. The number of seed per plant in the first year was found to be 16.71 in zeolite$^+$ and 15.87 in zeolite$^-$. Zeolite improves soil fertility and absorbs a high quantity of water (Susana *et al*. 2015). According to Ghanbari and Ariafar (2013), the seed number per plant increased with zeolite application. Excessive precipitation in the second year of the experiment may have obscured the effect of zeolite (Fig 1). In terms of nitrogen applications, barnyard manure gave the best results in both years. The control plots yielded the lowest seed number per plant (Table 4, 5). Barnyard manure protects soil moisture because it contains more organic matter and enriches the soil in terms of nutrients. Dogan (2019) investigated the effects of chemical and organic fertilizers on chickpea yield and yield components and obtained the lowest seed number per plant from control plots. Researchers reported that barnyard manure positively affected the seed number per plant.

In the first year of the experiment, irrigated + zeolite$^+$ + barnyard manure plots yielded the highest seed number per plant, while irrigated + zeolite$^-$ + barnyard manure plots showed a lower pod number per plant (Fig 2). The experiment did not record excessive precipitation in the first year. Barnyard manure + zeolite$^+$ plots may have given the best results because the zeolite absorbed water. The irrigated + zeolite$^-$ + barnyard manure plots yielded the highest seed number per plant in the second year of the experiment (Fig 2). Precipitation is very high in the second year of the experiment (Fig 1). The excessive precipitation prevented the observation of the zeolite's effect in the second year.

Grain yield per plant

Growing conditions and nitrogen applications had a significant impact on grain yield per plant in both years, respectively. Zeolite applications were significant in the first year but insignificant in the second year (Table 4, 5). In both years, the grain yield per plant was higher in irrigated conditions than in dry conditions. Agrawal *et al*. (2022) reported that with irrigation in chickpeas, grain yield per plant increased. The grain yield per plant was identified as 7.88 g in zeolite$^+$ and 7.13 g in zeolite$^-$ during the first year. The zeolite application increased grain yield per plant. Zeolite improves soil fertility and absorbs a high quantity of water (Susana *et al*., 2015). According to Kazan (2007), zeolite application in chickpea increased grain yield per plant. Excessive precipitation in the second year of the experiment may have obscured the effect of zeolite (Fig 1). In terms of nitrogen applications, barnyard manure gave the best results in both years. The control plots yielded the lowest grain

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}
Barnyard manure	Before sowing	20 tons ha^{-1}
Isabion	Before flowering	3000 ml ha^{-1}

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

	Seed number per plant	Grain yield per plant (g)	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Protein content (%)
Dry	12.41b	5.30b	2410b	1180b	22.5a
Irrigated	20.17a	9.71a	4350a	2140a	21.6b
Mean	16.29	7.50	3385	1660	22.0
Zeolite^{+}	16.71a	7.88a	3510a	1730a	21.9b
Zeolite^{-}	15.87b	7.13b	3260b	1590b	22.2a
Mean	16.29	7.50	3385	1660	22.0
Control	13.54d	6.26e	2860d	1380e	21.7b
Traditional	15.43c	7.26c	3320b	1630c	22.1a
Chemical	17.26b	7.76b	3440b	1720b	22.2a
Barnyard manure	19.44a	9.45a	4210a	2070a	22.0a
Isabion	15.77c	6.80d	3090c	1510d	22.3a
Mean	16.29	7.50	3385	1660	22.0
General mean	16.29	7.50	3385	1660	22.0
Growing conditions (A)	**	**	**	**	**
Zeolite applications (B)	**	**	**	**	**
A×B	*	*	ns	ns	ns
Nitrogen applications (C)	**	**	**	**	**
A×C	**	**	**	**	**
B×C	**	**	ns	*	**
A×B×C	**	ns	ns	ns	**

ns: Non-significant, *: p≤0.05, **: p≤0.01.

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

	Seed number per plant	Grain yield per plant (g)	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Protein content (%)
Dry	29.46b	11.49b	6310b	2504b	22.9a
Irrigated	32.95a	14.79a	8020a	3253a	22.2b
Mean	31.20	13.14	7165	2879	22.5
Zeolite+	31.07	13.08	7060b	2876	22.7a
Zeolite-	31.33	13.20	7270a	2880	22.4b
Mean	31.20	13.14	7165	2879	22.5
Control	26.56d	11.32c	6280d	2467c	21.3b
Traditional	30.05c	13.15b	7170b	2880b	22.8a
Chemical	34.08b	13.02b	7210b	2867a	22.7a
Barnyard manure	35.94a	15.29a	8460a	3360a	23.3a
Isabion	29.38c	12.94b	6690c	2817b	22.7a
Mean	31.20	13.14	7165	2879	22.5
General mean	31.20	13.14	7165	2879	22.5
Growing conditions (A)	**	**	**	**	**
Zeolite applications (B)	ns	ns	*	ns	**
A×B	*	**	ns	ns	*
Nitrogen applications (C)	**	**	**	**	**
A×C	**	**	**	**	ns
B×C	**	**	**	**	ns
A×B×C	**	**	**	**	ns

ns: Non-significant, *: p≤0.05, **: p≤0.01.

yield per plant (Table 4, 5). Barnyard manure helps to retain soil moisture due to its higher organic matter content and nutrient enrichment properties. Ipeksen and Bicer (2021) reported that barnyard manure positively affects grain yield per plant in chickpeas.

In the first year, the application of zeolite shown elevated efficacy in irrigated regions, while exhibiting diminished effectiveness in dry areas. Therefore, the interaction of growing conditions × zeolite applications may have been important. Zeolite$^+$ + irrigated plots yielded the highest grain yield per plant (Fig 3). While high grain yield per plant were obtained in irrigated areas, low values were obtained in dry areas for all of the nitrogen applications in the first year. Therefore, the interaction of growing conditions × nitrogen applications may have been important. Barnyard manure + irrigated plots gave the best results (Fig 3). In the first year, the zeolite$^+$ plots yielded high grain yields per plant, while the zeolite$^-$ all nitrogen applications yielded low values. Therefore, the interaction between zeolite applications and nitrogen applications may have played a significant role. Barnyard manure + zeolite$^+$ plots yielded the best results (Fig 4). The irrigated + zeolite$^-$ + barnyard manure plots yielded the highest grain yield per plant, whereas the dry + zeolite$^-$ + Isabion manure plots showed a lower grain yield per plant in the second year of the experiment (Fig 4). In the second year of the experiment, the application of zeolite under dry growing conditions resulted in a higher grain yield per plant compared to the non-application of zeolite. The zeolite's water absorption property may not have been effective in the second year of the experiment due to excessive precipitation (Fig 1). In dry growing conditions, Isabion responded better to zeolite. Grain yield per plant was higher in zeolite$^+$ than zeolite$^-$ in dry conditions at Isabion plots.

Biological yield

Growing conditions, zeolite applications and nitrogen applications had a significant impact on biological yield in both years (Table 4, 5). In both years, biological yield was higher in irrigated conditions than in dry conditions. Biological yield is considerably affected by environmental conditions in chickpeas. Chickpea is a drought tolerant plant, but its response to irrigation is quite good (Arif *et al*., 2021). In this study, irrigation resulted in a corresponding

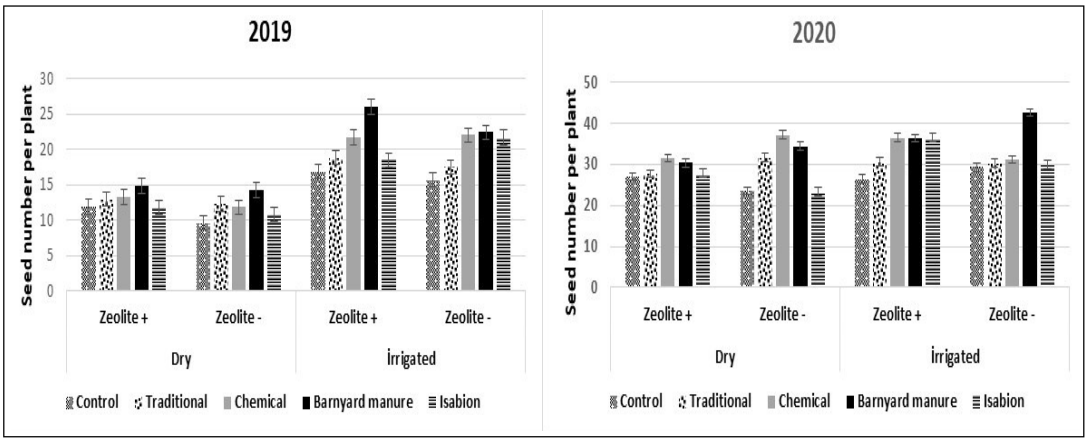


Fig 2: The interaction between growing conditions, zeolite applications and nitrogen applications seed number per plant of chickpea.

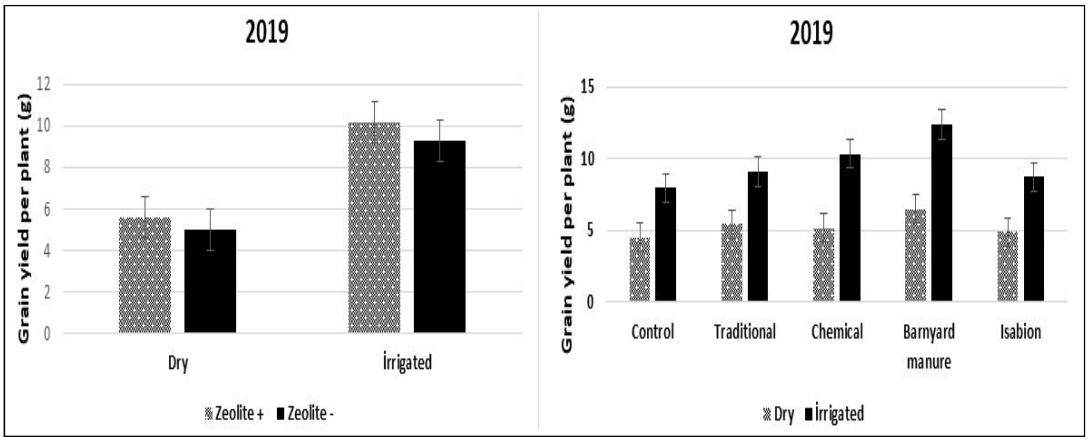


Fig 3: The interaction between growing conditions and zeolite applications (2019); the interaction between growing conditions and nitrogen applications (2019) for grain yield per plant of chickpea.

increase in biological yield: 80.5% in the first year and 27.1% in the second year. In the second year of research, the increase in biological yield may have been low due to high precipitation. Muruiki *et al.* (2021) found that there was a 27.7% increase in biological yield with irrigation in chickpeas. While the biological yield was higher in the zeolite^{+} plots in the first year, it was higher in the zeolite^{-} plots in the second year. Zeolite provides richer growing conditions for plants by preventing the leaching of water and nutrients. Zeolite increases the drought resistance of plants in semi-arid regions (Mondal *et al*., 2021). Amiri *et al.* (2021) reported that they achieved 45% more biological yield with zeolite application compared to control plots in soybeans. The biological yield was higher in the zeolite^{-} plots in the second year of the experiment. Excessive precipitation in the second year of the experiment may have obscured the effect of zeolite (Fig 1). Barnyard manure gave the best results both years, while control plots gave the worst results in terms of nitrogen applications. Barnyard manure, which contains excess organic matter and plant nutrients, has positive effects on biological yield. Pendergast *et al.* (2019) achieved 47% and 35% more biological yield at barnyard manure plots compared to chickpea control plots. Dogan (2019) reported that chicken and barnyard manure yielded the highest biological yield, while chickpea control plots yielded the lowest biological yield.

While the highest biological yield was obtained from irrigated × barnyard manure plots, the lowest was obtained from the dry × control plots in 2019. While irrigated + traditional fertilizer and Isabion fertilizer increased biological yield by 72%, barnyard manure increased it by 92%. Therefore, the interaction of growing conditions × nitrogen applications may have been important (Fig 5). In 2020, the irrigated + zeolite^{-} + barnyard manure plots yielded the highest biological yield, while the dry + zeolite^{-} + Isabion plots yielded the lowest. While zeolite^{-} + Isabion fertilizer plots gave the highest results in irrigated areas, zeolite^{-} + Isabion fertilizer plots gave the lowest results in dry areas in the second year. Therefore, the interaction of growing conditions x zeolite applications x nitrogen applications may have been important (Fig 5).

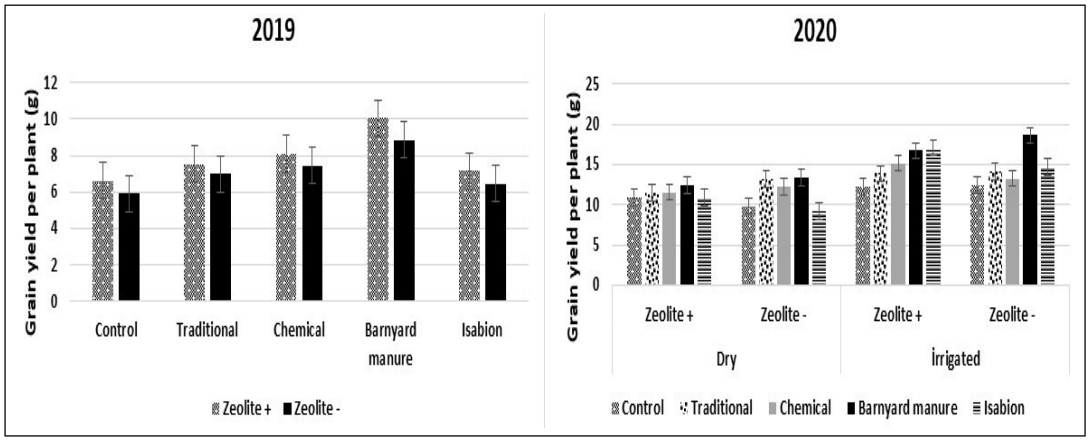


Fig 4: The interaction between zeolite applications and nitrogen applications (2019); the interaction between growing conditions, zeolite applications and nitrogen applications (2020) for grain yield per plant of chickpea.

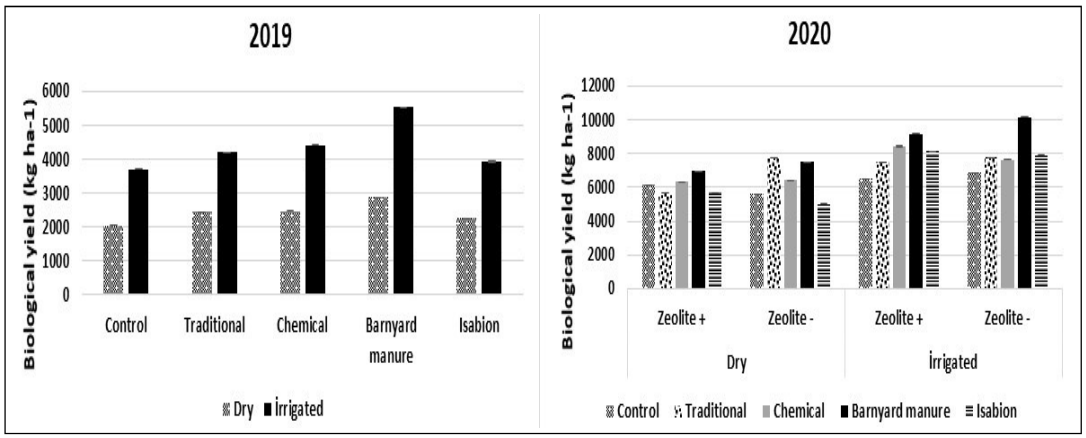


Fig 5: The interaction between growing conditions and nitrogen applications (2019); the interaction between growing conditions, zeolite applications and nitrogen applications (2020) for biological yield of chickpea.

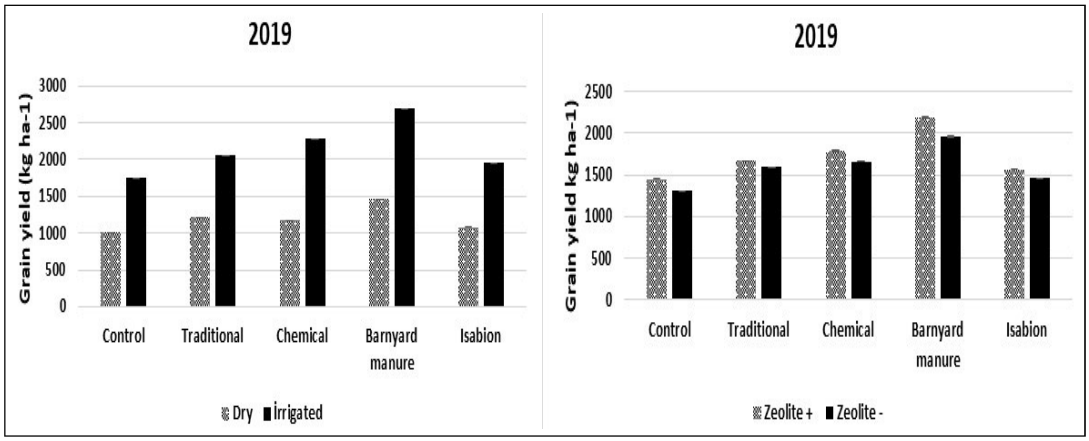


Fig 6: The interaction between growing conditions and nitrogen applications (2019); the interaction between zeolite applications and nitrogen applications (2019) for grain yield of chickpea

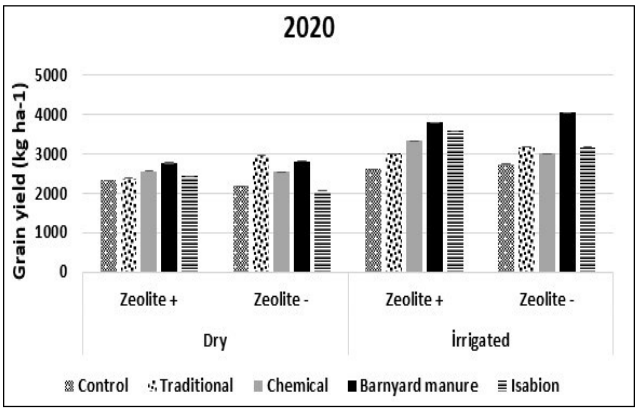


Fig 7: The interaction between growing conditions, zeolite applications and nitrogen applications (2020) for grain yield.

Grain yield

Growing conditions and nitrogen applications had a significant impact on grain yield in both years. Zeolite applications were significant in the first year but insignificant in the second year (Table 4, 5). In both years, the grain yield was higher in irrigated conditions than in dry conditions. Environmental conditions significantly influence the grain yield in chickpeas. Chickpea is a drought tolerant plant, but its response to irrigation is quite good (Arif *et al*., 2021). The experiment yielded 81% and 29% more grain in irrigated plots compared to dry plots in the first and second years, respectively. Muruiki *et al.* (2021) found that chickpea grain yield increased by 60.3% with irrigation. Gourav and Mishra (2019) reported that grain yield in pulses increased with irrigation. While grain yield was determined at 1730 kg ha^{-1} in $zeolite^{+}$, it was 1590 kg ha^{-1} in $zeolite^{-}$ in the first year. Zeolite provides richer growing conditions for plants by preventing the leaching of water and nutrients. Zeolite increases the drought resistance of plants in semi-arid regions (Mondal *et al*., 2021). Amiri *et al*. (2021) found that grain yield increased by 64% with zeolite application compared to control plots in soybeans. In the first year, the application of zeolite resulted in a rise in grain yield, however in the second year, no impact was observed. Both years were significantly affected by the growing conditions and nitrogen applications, resulting in a substantial impact on the grain yield per plant. In the second year of the experiment, sufficient precipitation and suitable climatic conditions prevented any determination of the zeolite's effect (Fig 1). Hoseini *et al.* (2020) reported that zeolite application did not affect grain yield in chickpeas. Barnyard manure gave the best results both years, while control plots gave the worst results in terms of nitrogen applications. Barnyard manure, which contains excess organic matter and plant nutrients, has positive effects on grain yield. Janmohammadi *et al*. (2018) found that applying organic fertilizer to chickpeas increased grain yield. Demir (2021) reported that the chicken manure plots yielded the highest grain, while the control plots yielded the lowest.

In the first year, all nitrogen applications yielded low values in dry areas, while irrigated areas yielded high grain yields. Therefore, the interaction of growing conditions x nitrogen applications may have been important. Barnyard manure + irrigated plots gave the best results (Fig 6). In the first year, the $zeolite^{+}$ plots yielded high grain yields, while the $zeolite^{-}$ all nitrogen applications yielded low values. Therefore, the interaction between zeolite applications and nitrogen applications may have played a significant role. The best results were obtained from barnyard manure + $zeolite^{+}$ plots (Fig 6). The irrigated + $zeolite^{-}$ + barnyard manure plots yielded the highest grain yield, whereas the dry + $zeolite^{-}$ + Isabion manure plots showed lower grain yields in the second year of the experiment (Fig 7). In the second year of the experiment, the application of zeolite under dry growing conditions resulted in a higher grain yield compared to traditional and barnyard manure plots. The zeolite's water absorption property may not have been effective in the second year of the experiment due to excessive precipitation (Fig 1). In dry

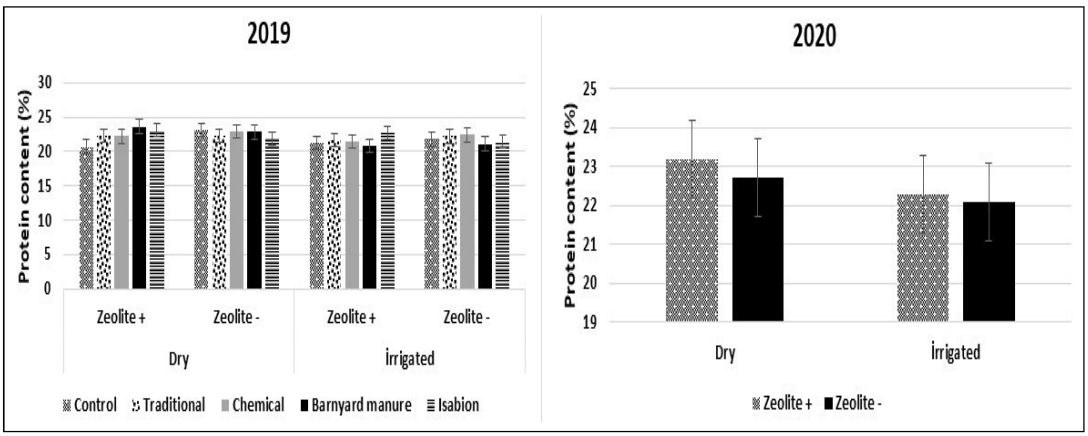


Fig 8: The interaction between growing conditions, zeolite applications and nitrogen applications (2019) for protein content of chickpea; the interaction between growing conditions and zeolite applications (2020) for protein content of chickpea.

growing conditions, Isabion responded better to zeolite. Grain yield was higher in zeolite$^+$ than zeolite$^-$ in dry conditions at Isabion plots.

Protein content

Growing conditions, zeolite applications and nitrogen applications had a significant impact on protein content in the first and second years (Table 4, 5). In both years, the protein content was higher in dry conditions than in irrigated conditions. Protein content generally increases due to decreased yield in arid conditions (Dupont *et al.,* 2006; Flagella *et al.,* 2010). Bicer *et al.* (2004) found that the protein content of chickpeas decreased with irrigation. While the protein content is higher in the zeolite$^-$ plots in the first year, it is higher in the zeolite$^+$ plots in the second year. Grain yield is higher in zeolite$^+$ plots in the first year. For this reason, the protein content was lower in the zeolite$^+$ plots. Yield and protein content are generally inversely proportional in arid conditions (Dupont *et al.,* 2006; Flagella *et al.,* 2010). Precipitation was too high in the second year (Fig 1) and the zeolite may have prevented the leaching of plant nutrients, especially nitrogen. Kharazmi and Tan (2020) found that zeolite application did not affect the crude protein, ADF and NDF rates in alfalfa. Tutar (2019) was unable to detect any effect of zeolite application on corn's crude protein ratio. In both years of research, protein content was higher in all nitrogen applications than control plots. The same statistical group included all nitrogen applications. Yagmur and Engin (2005) reported that chickpea protein content increased with increasing nitrogen doses.

While barnyard manure plots in irrigated areas have a low protein content, barnyard manure plots in dry areas have a higher protein content in the first year of the experiment. While the protein content is lower in the zeolite$^-$ plots, it is higher in the zeolite$^+$ plots. Therefore, the interaction between growing conditions, zeolite applications and nitrogen applications may have played a significant role (Fig 8). In the second year of experiments, the protein content in zeolite$^+$ plots is higher than in zeolite$^-$ plots, both in dry and irrigated growing conditions. Therefore, the interaction of growing conditions and zeolite applications may have been important (Fig 8). Protein content increased in both growing conditions with zeolite application.

CONCLUSION

The measured variables exhibited higher values in irrigated conditions compared to dry conditions, with the exception of protein content. Irrigation had a positive impact on grain yield and yield components. The significance of irrigation in chickpea cultivation in the Central Anatolia Region has been established, except during years with abundant rainfall. Normal precipitation was observed in the first year of the experiment and zeolite application had a positive effect on yield and yield components. Zeolite improves crop yield and yield components by effectively absorbing and retaining water and essential plant nutrients that would otherwise be lost through soil leaching. Nevertheless, during the second year of the experiment, the zeolite treatment was rendered ineffective due to an abundance of precipitation. The positive effects of different nitrogen applications on yield and yield components were determined in chickpeas. It is advisable for farmers in Türkiye to apply nitrogen to their crops due to the recent rise in their earnings from chickpeas. Barnyard manure enhances crop productivity and yield components to a greater extent compared to other nitrogen applications due to its rich content of plant nutrients and organic matter. Additionally, it has the ability to retain water and maintain soil temperature at a higher level.

Using barnyard manure is advised to enhance the efficiency of chickpea production. If the exorbitant expense of barnyard manure prohibits its utilization, one may choose to employ chemical or conventional fertilizers instead. If the zeolite treatment does not result in a significant cost rise, it is advisable to use it. Furthermore, it is advisable to enhance chickpea cultivation in irrigated environments.

ACKNOWLEDGEMENT

This study is derived from Engin TAKIL's PhD thesis.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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