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Original Research

Effects of Vermicompost and Microbial Fertilizers on Yield and Quality Traits of Chickpea (*Cicer arietinum* L.)

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Abstract

This study aimed to determine the effects of different microbial fertilizers and vermicompost levels on yield and quality traits of two chickpea (*Cicer arietinum* L.) cultivars under Fethiye (Muğla) ecological conditions during the 2018 and 2019 growing seasons. İnci and Hasanbey cultivars were evaluated using two microbial fertilizers (*Rhizobium ciceri* and *Bacillus megaterium*) and four vermicompost doses (0, 2500, 5000, and 7500 kg ha^{-1}) in a split-split plot design with three replications. The treatments significantly affected biological yield, harvest index, hundred-grain weight, protein ratio, phosphorus content, and nodulation characteristics. Across both years, İnci produced a higher biological yield (5757 kg ha^{-1}) than Hasanbey (5542 kg ha^{-1}). Vermicompost applications increased biological yield from 4994 kg ha^{-1} (0 kg ha^{-1}) to 6167 kg ha^{-1} (5000 kg ha^{-1}). *Rhizobium* inoculation improved biological yield to 5781 kg ha^{-1} compared with the control (5419 kg ha^{-1}). The harvest index ranged between 25.1 and 27.9%, with higher values generally observed in Hasanbey. Hundred-grain weight varied between 37.2-38.5 g in the combined analysis, with the highest values obtained from 5000 kg ha^{-1} vermicompost and *Bacillus* treatments. Protein ratio increased from 20.3% in Hasanbey to 21.1% in İnci, and microbial fertilizers – particularly *Rhizobium* – enhanced protein content. Vermicompost and microbial fertilizers also improved nodule number and nodule fresh weight. Overall, the combined use of vermicompost (5000-7500 kg ha^{-1}) and microbial fertilizers, especially *Rhizobium*, enhanced yield and quality traits in chickpea under the ecological conditions of Fethiye.

Keywords: chickpea, microbial fertilizer, vermicompost, yield, quality traits

Introduction

Chickpea is an edible legume plant that has been used in both human and animal nutrition since ancient times. Its dry grains contain 18-31% protein with 76-88% digestibility and are rich in essential amino acids and various minerals. Since legumes are vital sources of protein, calcium, iron, phosphorus, and other minerals, they form a significant part of the diet of vegetarians since the other food items they consume do not contain much protein [1]. It is known that chickpea cultivation, which has an important place in human

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and animal nutrition, has been carried out for 8000 years [2]. On the other hand, nutrients such as N, Ca, P, and K in the roots remain in the root zone of the soil as a result of decomposition [3]. It is accepted that approximately 25% of the *Rhizobium* bacteria population naturally found in the soil is effective in biological nitrogen fixation. In order to increase this rate, seeds should be inoculated with specially prepared bacterial cultures. Soil moisture significantly affects the survival and reproduction of *Rhizobium* bacteria added to the soil by grafting. Too little or too much moisture in the soil causes bacteria to be largely destroyed. It is a well-known fact that increasing crop production and farmers' income depends on increasing productivity, and one of the most effective ways to improve productivity is the use of correct fertilizers. Although the share of fertilizers in productivity increase varies according to conditions, it is generally stated to be around 50% [4]. Among the aims of organic agriculture are the enrichment of biodiversity, the biological cycle, and biological activity in the soil in order to ensure the social, ecological, and economic sustainability of natural systems. The effect of organic matter can be direct or indirect. Organic matter plays a direct role as a source of plant nutrients and also affects the physical and chemical properties of the soil. Excessive chemical fertilization used in agriculture causes some nutrients to decrease and some to accumulate excessively. The best way to keep the organic matter in the soil at the maximum level is organic fertilization [5, 6].

Materials and Methods

In the study, İnci and Hasanbey chickpea cultivars were used as material, *Rhizobium ciceri* as nitrogen-fixing bacteria, and *Bacillus megaterium* as phosphate-solubilizing bacteria. In addition, vermicompost containing 2% N, 1% P_2O_5, 1% K_2O, and 3% Ca was used. This study was carried out in the Kayaköy neighborhood of Fethiye district of Muğla province in 2018 and 2019. The effects of two chickpea cultivars, two different bacterial species (nitrogen-fixing *Rhizobium* bacteria, phosphate-dissolving bacteria), and four different doses of vermicompost (0, 2500, 5000, and 7500 kg ha^{-1}) on yield, quality, and nodulation were investigated.

The long-term average annual precipitation of the study area is 170.3 mm, with an average temperature of 20.64ºC and an average relative humidity of 63.32%. During the 2017-2018 and 2018-2019 growing seasons, the total precipitation was 118.6 mm and 160.5 mm, respectively. The mean temperatures were 23.08ºC in the first year and 21.54ºC in the second year. The average relative humidity values were 61.6% in the first year and 59.46% in the second year [7].

According to the soil analysis results, the soil sample taken from the experimental area in 2018 was classified as clay-loam in texture, slightly alkaline in reaction, medium in organic matter content, rich in lime, slightly saline, medium in potassium and phosphorus levels, and deficient in zinc. Based on the 2019 analysis results, the soil sample from the same area was also clay-loam in texture and slightly alkaline, with medium organic matter content; however, its lime content was lower compared to the first year. The soil remained slightly saline, with medium potassium and phosphorus levels, and continued to be deficient in zinc.

The experiments were conducted using a randomized complete block design with a split-split plot arrangement and three replications. Cultivars were assigned to the main plots, bacterial treatments to the sub-plots, and vermicompost doses to the sub-sub plots. A total of 72 plots were established. Each plot consisted of five rows, with a row spacing of 30 cm, and the plot size was arranged as 1.5 m × 5 m (7.5 m^2). The seed rate was calculated to ensure that approximately 60 seeds were sown per square meter.

The *Rhizobium ciceri* strain used in the experiment was obtained from the Ankara Soil and Fertilizer Research Institute and stored under refrigeration until use. A few hours before sowing, chickpea seeds were moistened with a sugar solution and thoroughly mixed with the inoculant to ensure effective inoculation. Nodulation was verified at the flowering stage by examining root nodules. *Bacillus megaterium*, supplied by the Department of Plant Protection, Faculty of Agriculture, Atatürk University, was propagated under laboratory conditions and prepared as a liquid suspension. It was applied to the seeds immediately prior to sowing using seed coating. Vermicompost was broadcast onto the soil surface before sowing and incorporated with a rake at rates equivalent to 0, 2500, 5000, and 7500 kg ha^{-1}. Weed control was performed mechanically twice, once before flowering and once after flowering. The experiment was conducted under dry farming conditions. Harvesting was carried out manually at physiological maturity, when pods turned yellow but before shattering, on July 6, 2018, and June 30, 2019, respectively. Post-harvest residues were removed to avoid cross-contamination between plots.

At harvest, plants within 50 cm on each side of the five rows forming the plot and within 50 cm of the row heads were excluded from observation as an edge effect. All observations were carried out on 10 randomly selected plants from 0.9 m × 4 m = 3.6 m^2 areas.

The crop was harvested at physiological maturity, when the pods had turned yellow but before pod shattering occurred. All harvested plants were measured, counted, and hand-threshed with care, and mean values were calculated based on the observations. Plot yields were determined by threshing the plants manually and converting the results to yield per hectare. After completing all treatments applied to the chickpea cultivars, the data were subjected to analysis of variance (ANOVA) appropriate for the split–split plot design. Mean separations were performed using Duncan's multiple range test at the 5% significance level

[8]. Statistical analyses were carried out using the JMP (SAS Institute, USA) and Costat software packages.

Results and Discussion

The yield, quality, and nodule trait values of the İnci and Hasanbey chickpea cultivars were determined as described in the Materials and Methods section. Mean comparisons for all examined traits were performed using Duncan's multiple range test at the 5% significance level.

Biological Yield

The mean biological yield values and the corresponding group classifications for the two chickpea cultivars under different vermicompost doses and microbial fertilizer treatments are presented in Table 1.

In both years of the experiment and in the two-year combined averages, the average biological yield values obtained from İnci and Hasanbey chickpea cultivars were found to be 5493-5226 kg ha^{-1} in 2018, 6021-5858 kg ha^{-1} in 2019, and 5757-5542 kg ha^{-1} in the combined averages of the two years, respectively. The highest values in the years when the study was carried out and in the combined averages of the two years were obtained from the İnci cultivar (Table 1). [9] reported that the biological average yield values of the chickpea cultivars he used in his chickpea adaptation study carried out under Van ecological conditions varied between 1719-3133 kg ha^{-1}. [10] reported that vermicompost and leonardite applications significantly improved biological yield and nutrient content in chickpea. Similarly, [11] found that NPK combined with vermicompost enhanced growth characteristics and biological yield. [12] also confirmed that phosphorus fertilization and bacterial inoculation positively influenced chickpea yield and nutrient uptake. The discrepancies between the findings obtained by some researchers and those obtained in this study are thought to be due to differences in climatic conditions and application techniques.

The general biological yield averages obtained from vermicompost dose applications varied between 4873-5853 kg ha^{-1} in 2018, 5114-6773 kg ha^{-1} in 2019, and 4994-6167 kg ha^{-1} in the combined averages of the two years. While the lowest biological yield values were obtained from the plots where no vermicompost was applied (0 kg ha^{-1}) in both years in which the study was conducted and in the combined averages of the two years, they were obtained from the 7500 kg ha^{-1} vermicompost application in 2018. Although the highest values in 2019 and in the combined averages of the two years were obtained from 5000 kg ha^{-1} vermicompost application, the result was in the same group as the 7500 kg ha^{-1} vermicompost application in the combined averages of the two years (Table 1). [10] reported that vermicompost and leonardite applications significantly improved biological yield and nutrient content in

Table 1. Biological yield (kg ha^{-1}) of chickpea cultivars under microbial fertilizer and vermicompost treatments.

Traits	Year	Cultivar	Microbial fertilizers / Vermicompost levels (kg ha^{-1})											
			Control				*Rhizobium*				*Bacillus*			
			0	2500	5000	7500	0	2500	5000	7500	0	2500	5000	7500
Biological yield	2018	İnci	4141^{k}	4528^{j}	5428^{ef}	6213^{a}	5233^{fg}	4943^{ghi}	5697^{cde}	5959^{abc}	5583^{de}	6136^{a}	6059^{ab}	6003^{abc}
		Hasanbey	4820^{hij}	4806^{hij}	4777^{hij}	6140^{a}	4738^{hij}	5484^{ef}	5539^{def}	5093^{gh}	4723^{ij}	5022g^{hi}	5863^{a-d}	5711^{b-e}
	2019	İnci	4401^{mn}	5524^{kl}	7646^{a}	7000^{bc}	6763^{c-f}	5769^{h-l}	6925^{cd}	6827^{cde}	4235^{mn}	4666^{m}	6247^{f-i}	6240^{f-i}
		Hasanbey	4022^{n}	5261^{l}	5913^{g-k}	6083^{g-j}	5544^{jkl}	6203^{ghi}	6445^{d-g}	5337^{l}	5720^{i-l}	5983^{g-k}	7464^{ab}	6325^{c-h}
	2018-19	İnci	4271^{k}	5026^{hi}	6537^{abc}	6607^{ab}	4271^{k}	5026^{hi}	6537^{abc}	6607^{ab}	4909ij	5402^{ghi}	6153^{a-e}	6122^{b-e}
		Hasanbey	4421^{jk}	5034^{hi}	5345^{ghi}	6112^{b-e}	5141^{hi}	5844^{efg}	5992^{def}	5215^{hi}	5222^{hi}	5503^{fgh}	6664^{a}	6018^{c-f}
			2018				2019				2018-19			
General mean	Cultivar		5493^{A}	5226^{A}	-	-	6021	5858	-	-	5757^{A}	5542^{B}	-	-
	Vermicompost		4873^{D}	5153^{C}	5561^{B}	5853^{A}	5114^{D}	5568^{C}	6773^{A}	6302^{B}	4994^{C}	5361^{B}	6167^{A}	6077^{A}
	Microbial fertilizer		5106^{C}	5336^{B}	5637^{A}	-	5731^{B}	6272^{A}	5860^{B}	-	5419^{B}	5781^{A}	5748^{A}	-

*Means followed by the same letter are not significantly different at $p \leq 0.05$ according to Duncan's multiple range test.

chickpea. Similarly, [11] found that NPK combined with vermicompost enhanced growth characteristics and biological yield, with differences between higher vermicompost doses not being statistically significant. The findings obtained from this study are partially similar to the findings obtained by the researchers in question.

The general average biological yield values obtained from bacteria applications were 5106-5637 kg ha^{-1} in the first year, 5731-6272 kg ha^{-1} in the second year, and the combined averages of the two years were 5419-5781 kg ha^{-1}. In the first year and two years' combined averages, the lowest values were obtained from the control plots without bacteria application, while in the second year, *Bacillus* bacteria were applied, but they were in the same letter group as the control plots without bacteria application. The highest value in the first year of the study was obtained from the application of *Bacillus* bacteria. In the second year of the study and in the combined averages, the highest values were obtained from the *Rhizobium* bacteria application, but in the two years' combined averages, they were in the same letter group as the *Rhizobium* bacteria application (Table 1). The interaction effects of bacteria × vermicompost are illustrated in Fig. 1. [12] reported that phosphorus fertilization combined with bacterial inoculation significantly increased biological yield in chickpea. [13] further emphasized that symbiotic nitrogen fixation and appropriate bacterial strains are critical for sustaining chickpea productivity under varying climatic conditions. The findings in this study are similar to those obtained by these researchers. In particular, the increase in biological yield under *Rhizobium* inoculation can be explained by enhanced nitrogen fixation, which supported vegetative growth and biomass accumulation. *Bacillus* inoculation contributed by improving phosphorus solubilization and nutrient uptake, thereby strengthening root development and overall plant productivity. Vermicompost further enriched soil organic matter, creating favorable conditions for microbe–soil–plant interactions that sustained higher biological yield.

Harvest Index

The mean harvest index values and the corresponding group classifications for the two chickpea cultivars under different vermicompost doses and microbial fertilizer treatments are presented in Table 2.

In both years and in the combined averages of the two years in which the study was conducted, the average harvest index values obtained from İnci and Hasanbey cultivars were found to be 25.5-25.8% in 2018, 24.7-30% in 2019, and 25.1-27.9% in the combined averages of the two years, respectively. The harvest index values measured in the Hasanbey cultivar in the years and in the combined averages of the two years in which the study was conducted were found to be higher than the values measured in the İnci cultivar (Table 2). [9] reported that the harvest index averages of the chickpea cultivars used in the study conducted in the Van ecological conditions varied between 40.00-42.33%, and [14] reported that harvest index values varied significantly among chickpea genotypes depending on phenology and genetic background.

The overall plant harvest index averages obtained from vermicompost dose applications varied between 24.5-27.1% in 2018, 25.7-28.8% in 2019, and 25.1-27.9% in the combined averages of the two years, and the lowest harvest index values were obtained from the 7500 kg ha^{-1} vermicompost application. While the highest harvest index values were obtained from the 2500 kg ha^{-1} vermicompost application in 2019, the difference between them and the 5000 kg ha^{-1} vermicompost application was not found to be statistically significant (Table 2). The main effects of vermicompost are illustrated in Fig. 2. [15], in his study conducted in the Mardin ecological conditions, found that the effect of different applications on the harvest

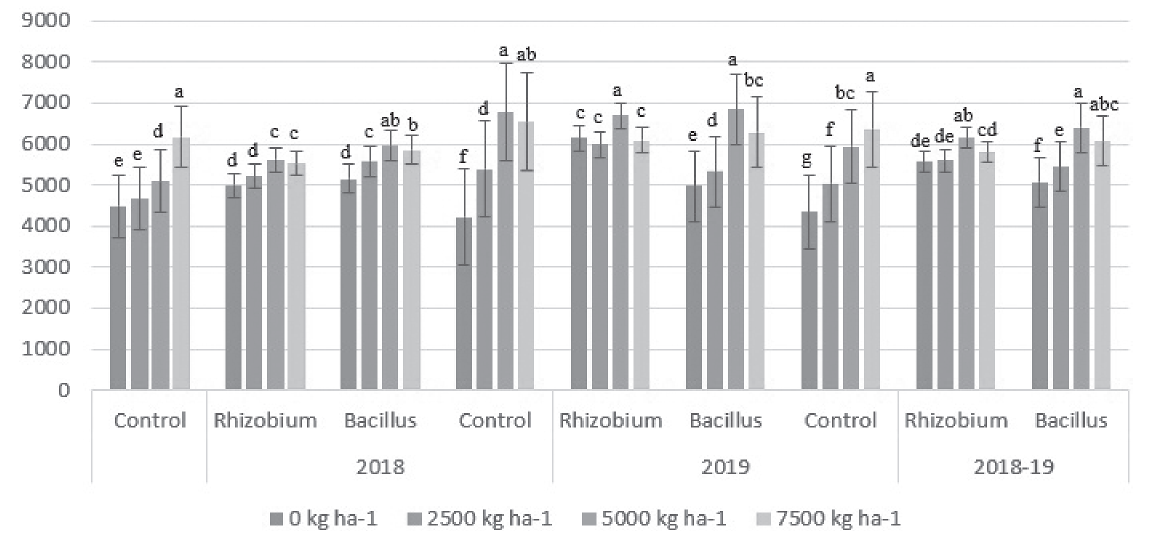

Fig. 1. Biological yield (kg ha^{-1}) of chickpea cultivars under vermicompost doses and microbial fertilizer treatments.

index was significant; it was stated that the lowest harvest index value (28.3%) was obtained from the untreated plots, followed by the DAP/2 application, the highest harvest index value (33.0%) was obtained from the chicken manure application, followed by the farm manure and vermicompost applications, and similar results were obtained. [14] also reported that harvest index values varied significantly among chickpea genotypes depending on phenology and genetic background, supporting our findings. Our findings are similar to those obtained by the researchers.

The harvest index values obtained from the bacterial species applied in the study varied between 25.2-26.2% in the first year of the study, 26.7-27.9% in the second year, and 26.2-26.8% in the combined averages of the two years. The lowest values were obtained from the application of *Bacillus* bacteria in the first year, and from the control plots without bacteria application in the second and the two-year combined averages. The highest values were obtained from the *Rhizobium* bacteria application in the first year and two-year combined averages of the study, and from the *Bacillus* bacteria application in the second year of the study (Table 2). [16] reported that when fertilizer applications were compared in his study, the highest harvest index value was obtained in bacterial inoculation, and the lowest harvest index value was obtained in plots applied with farmyard manure. [17] reported that the harvest index was higher in plants applied with *Rhizobium* bacteria compared to control doses. [18] reported that different *Rhizobium* isolates significantly affected yield attributes and harvest index values in chickpea. In our study, the variation in harvest index under *Rhizobium* inoculation can be explained by enhanced biological nitrogen fixation, which increased assimilate production and allocation to seeds. *Bacillus* inoculation contributed by improving phosphorus availability, thereby supporting energy metabolism and more efficient partitioning of assimilates, resulting in higher harvest index values.

Hundred-Grain Weight

The mean hundred-grain weight values and the corresponding group classifications for the two chickpea cultivars under different vermicompost doses and microbial fertilizer treatments are presented in Table 3.

In the years when the study was conducted and in the combined averages of the two years, the mean hundred-grain weight values obtained from İnci and Hasanbey chickpea cultivars were found to be 39.9-37.2 g in the first year of the study, 35.5-38.4 g in the second year, and 37.7-37.7 g in the combined averages of the two years, respectively. The hundred-grain weight values measured in the İnci cultivar in the first year of the study were found to be higher than in the Hasanbey cultivar. In the second year of the study, the hundred-grain weight values obtained from the Hasanbey cultivar were found to be higher than in the İnci cultivar. The hundred-grain weight values obtained from

Table 2. Harvest index (%) of chickpea cultivars as affected by microbial fertilizer and vermicompost treatments.

			Microbial fertilizers / Vermicompost levels (kg ha^{-1})											
			Control				*Rhizobium*				*Bacillus*			
Traits	Year	Cultivar	0	2500	5000	7500	0	2500	5000	7500	0	2500	5000	7500
Harvest index	2018	İnci	27.2^{abc}	27.9^{ab}	24.9^{e-h}	24.7^{fgh}	25.1^{efg}	27.7^{ab}	25.4^{d-g}	25.9^{c-f}	23.8^{g-j}	25.4^{d-g}	25.1^{efg}	23.3^{hij}
		Hasanbey	22.4j	27.1^{a-d}	27.8^{ab}	24.1^{ghı}	27.3^{abc}	26.6^{a-e}	25.3^{efg}	26.2^{b-f}	27.9^{a}	28.1^{a}	24.9^{fgh}	22.7^{ıj}
	2019	İnci	24.1^{ijk}	22.6^{jk}	23.0^{jk}	22.4^{jk}	21.4^{k}	27.1^{gh}	24.4^{ij}	22.0^{jk}	27.0^{gh}	29.3^{j-g}	29.2^{c-h}	24.2^{ij}
		Hasanbey	28.2^{eh}	31.9^{abc}	33.5^{a}	27.9^{fgh}	30.9^{a-e}	31.1^{a-d}	32.2^{ab}	30.9^{a-e}	28.6^{d-h}	30.5^{b-f}	27.9^{fgh}	26.4^{h-i}
	2018-19	İnci	25.6 $^{e-i}$	25.3^{e-i}	23.9^{ghi}	23.6^{hi}	23.2^{i}	27.4^{b-e}	24.9^{e-i}	24.0^{ghi}	25.4^{e-i}	27.4^{b-e}	27.1^{b-f}	23.8^{hi}
		Hasanbey	25.3^{e-i}	29.5^{ab}	30.7^{a}	26.0^{d-h}	29.1^{ab}	28.8^{abc}	28.8^{abc}	28.6^{a-d}	28.3^{a-d}	29.3^{ab}	26.4^{c-g}	24.5^{f-i}
General mean			2018				2019				2018-19			
	Cultivar		25.5^{B}	25.8^{A}	-	-	24.7^{B}	30.0^{A}	-	-	25.1^{B}	27.9^{A}	-	-
	Vermicompost		25.6^{B}	27.1^{A}	25.5^{B}	24.5^{C}	26.7^{B}	28.8^{A}	28.4^{A}	25.7^{C}	26.2^{C}	27.9^{A}	26.9^{B}	25.1^{D}
	Microbial fertilizer		25.7^{B}	26.2^{A}	25.2^{C}	-	26.7^{B}	27.5^{AB}	27.9^{A}	-	26.2^{B}	26.8^{A}	26.5^{AB}	-

*Means followed by the same letter are not significantly different at $p \leq 0.05$ according to Duncan's multiple range test.

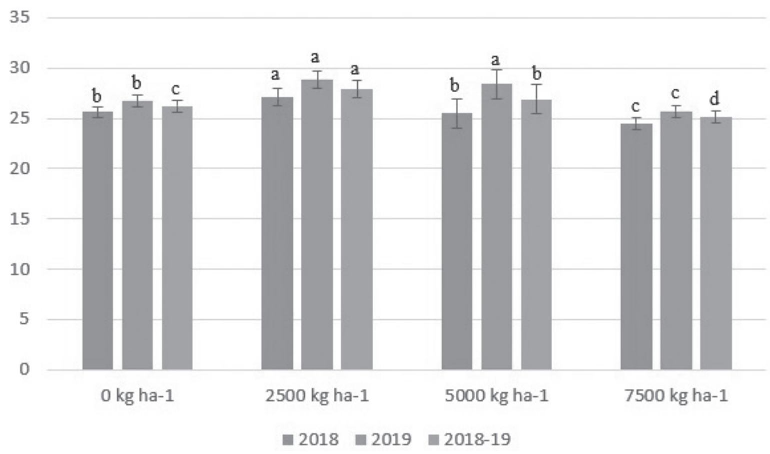

Fig. 2. Harvest index (%) of chickpea cultivars under vermicompost doses.

the cultivars in the combined averages of the two years were found to be equal (Table 3). [9] reported that the average hundred-grain weight of chickpea cultivars used in a study conducted under Van ecological conditions varied between 32.2 and 39.66 g; [17] reported that the hundred-grain weight varied significantly depending on Rhizobia and phosphate-solubilizing bacteria applications. Our findings are parallel to the findings of the researchers.

The overall hundred-grain weight averages obtained from vermicompost doses varied between 38.0-38.8 g in 2018, 36.3-37.5 g in 2019, and 37.2-38.2 g in the two-year combined averages. The lowest values were obtained from plots where no vermicompost was applied (0 kg ha^{-1}) in the years the study was conducted and in the two-year combined averages, while the highest values were obtained from plots where 5000 kg ha^{-1} vermicompost was applied (Table 3). [15] reported in his study that the effect of different applications on 100-grain weight was significant, with the lowest 100-grain weight values being obtained from plots where no application was made, and the highest 100-grain weight values were obtained from plots where chicken manure was applied. [19] reported that the lowest hundred-grain weight values were obtained from untreated (control) plots in their study, while plots where commercial fertilizer and vermicompost were applied were in the same letter group. [20] reported that organic manures and biofertilizers significantly improved hundred-grain weight and seed quality traits in chickpea.

The overall average hundred grain weight values obtained from the bacterial species applied in the study varied between 38.0-39.0 g in 2018, 36.8-37.1 g in 2019, and 37.5-38.1 g in the two-year combined averages. The lowest values were obtained from the control plots where no bacteria were applied in 2018

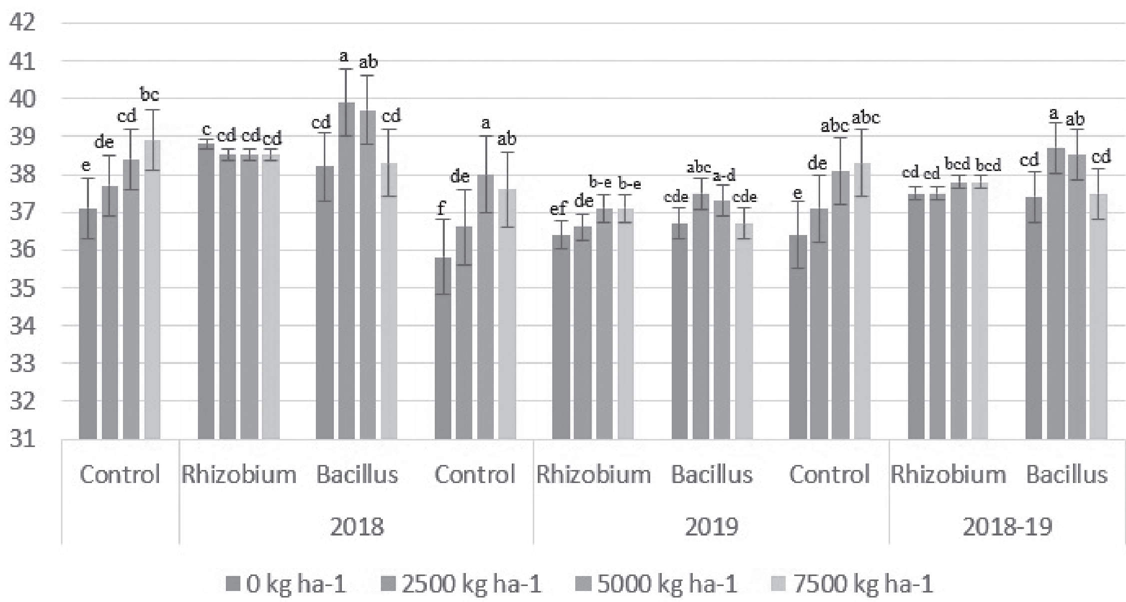

Fig. 3. Hundred-grain weight (g) of chickpea cultivars under vermicompost and microbial fertilizer interaction.

and in the two-year combined averages, and they were in the same group as the *Rhizobium*-applied plots in the two-year combined averages. The highest values were obtained from *Bacillus*-applied plots in 2018 and in the two-year combined averages. The values obtained in 2019 (36.8-37.1 g) were not found to be statistically significant (Table 3). The interaction effects of bacteria × vermicompost are illustrated in Fig. 3. [17] reported that the maximum 100-grain weight from seedbeds cultivated using conventional tillage was obtained from plots treated with 60 kg ha^{-1} P_2O_5 along with Rhizobia and phosphate-solubilizing bacteria. [21] reported that phosphorus plus biofertilizer applications under rainfed conditions significantly improved yield attributes, including hundred-grain weight. [22] showed that PGPR-based biofertilizers enhanced nutrient uptake and yield components of chickpea in arid environments. In our study, the increase in hundred-grain weight under *Bacillus* inoculation can be explained by improved phosphorus solubilization, which enhanced nutrient uptake and seed filling. *Rhizobium* inoculation contributed through biological nitrogen fixation, supporting assimilate production and allocation to seeds, thereby improving seed weight and quality traits.

Protein Content

The mean protein content values and the corresponding group classifications for the two chickpea cultivars under different vermicompost doses and microbial fertilizer treatments are presented in Table 4.

In the years when the study was conducted and in the combined averages of the two years, the average protein ratios obtained from İnci and Hasanbey cultivars were found to be 20.2-19.7% in the first year of the study, 22.1-20.8% in the second year, and 21.1-20.3% in the combined averages of the two years, respectively. The protein content values measured in the İnci cultivar in the years when the study was conducted and in the combined averages of the two years were found to be higher than the values measured in the Hasanbey cultivar (Table 4). The varietal differences are illustrated in Fig. 4. [9], in his cultivar adaptation study conducted in Van ecological conditions, stated that the average protein ratio in the grains of the cultivars varied between 20.32-24.35%. [23], in their study, reported that bio-based and synthetic phosphorus applications significantly influenced protein content in chickpea genotypes. [15] reported that the protein ratios for cultivars varied between 21.1-23.2% as a result of their study. Our findings are parallel to those obtained by the researchers.

The overall average protein content values obtained from vermicompost dose applications varied between 19.6-20.2% in 2018, 21.0-21.9% in 2019, and 20.3-21.1% in the combined two-year averages. In both years and the combined two-year averages, the lowest values were obtained from plots without vermicompost (0 kg ha^{-1}), and the highest values were obtained from the

Table 3. Hundred-grain weight (g) of chickpea cultivars under microbial fertilizer and vermicompost treatments.

			Microbial fertilizers / Vermicompost levels (kg ha^{-1})											
			Control				*Rhizobium*				*Bacillus*			
Traits	Year	Cultivar	0	2500	5000	7500	0	2500	5000	7500	0	2500	5000	7500
Hundred-grain weight	2018	İnci	38.4^{efg}	39.1^{cde}	38.9^{def}	40.7^{ab}	40.6^{ab}	40.3^{abc}	40.4^{abc}	40.0^{a-d}	38.7^{ef}	40.3^{abc}	41.0^{a}	40.7^{ab}
		Hasanbey	35.7^{j}	36.4^{ij}	37.8^{fgh}	37.2^{ghi}	36.8^{hij}	36.7^{hij}	36.7^{hij}	36.9^{hij}	37.7^{fgh}	39.6^{b-e}	38.4^{efg}	35.9^{j}
	2019	İnci	34.3	35.0	36.5	36.2	35.2	35.3	35.3	35.5	35.5	36.3	36.2	35.0
		Hasanbey	37.2	38.2	39.5	39.2	37.6	38.0	38.8	38.8	38.0	38.7	38.5	38.5
	2018-19	İnci	36.4^{f}	37.1^{def}	37.7^{b-f}	38.5^{a-d}	37.9^{a-d}	37.8^{a-e}	37.9^{a-d}	37.7^{a-f}	37.1^{def}	38.3^{a-d}	38.5^{abc}	37.9^{a-d}
		Hasanbey	36.4^{ef}	37.3^{b-f}	38.7^{ab}	38.2^{a-d}	37. 3^{c-f}	37.4^{b-f}	37.8^{a-f}	37.9^{a-d}	37.9^{a-d}	39.1^{a}	38.5^{a-d}	37.2^{c-f}
General mean			2018				2019				2018-19			
	Cultivar		39.9^{A}	37.2^{B}	-	-	35.5^{B}	38.4^{A}	-	-	37.7	37.7	-	-
	Vermicompost		38.0^{B}	38.7^{A}	38.8^{A}	38.5^{A}	36.3^{C}	36.9^{B}	37.5^{A}	37.2^{AB}	37.2^{C}	37.8^{B}	38.2^{A}	37.8^{AB}
	Microbial fertilizer		38.0^{C}	38.5^{B}	39.0^{A}	-	37.0	36.8	37.1	-	37.5^{B}	37.7^{B}	38.1^{A}	-

*Means followed by the same letter are not significantly different at $p \leq 0.05$ according to Duncan's multiple range test.

7500 kg ha⁻¹ vermicompost application (Table 4). [24] stated in his study that the average protein content in the grain obtained from different fertilizations varied between 19.7-23.8%. [25] reported that legume-derived biological nitrogen fixation contributes to sustainable nutrient management and indirectly supports protein accumulation in grains. Our findings are similar to those obtained by the researchers.

The average protein ratios obtained from the bacterial species applied in the study ranged from 19.1 to 20.8% in the first year of the study, from 20.5 to 22.5% in the second year, and from 19.8 to 21.6% in the two-year combined means, with the lowest values obtained from the control plots without bacterial application. The highest values were obtained from the *Bacillus* bacteria application in the first year of the study, while the highest values in the second year and in the two-year combined means were obtained from the *Rhizobium* bacteria application (Table 4). [26] reported that the co-application of phosphorus fertilizers, organic manures, and *Bacillus* sp. MN-54 significantly improved nutrient uptake, yield, and protein content in chickpea. [16] reported that when comparing fertilizer applications, all applications (bacterial inoculation, barnyard manure, chemical fertilization, and rose pulp applications) yielded protein levels similar to the control application, and that different fertilizer treatments did not affect protein levels. In contrast, our study demonstrated that *Rhizobium* inoculation increased protein content through enhanced biological nitrogen fixation, directly supporting amino acid and protein synthesis. *Bacillus* inoculation contributed indirectly by improving phosphorus availability, thereby supporting energy metabolism and facilitating protein accumulation in chickpea grains.

Phosphorus Content

The mean phosphorus content values and the corresponding group classifications for the two chickpea cultivars under different vermicompost doses and microbial fertilizer treatments are presented in Table 5.

In both years and in the combined two-year averages, the average grain phosphorus content values obtained in İnci and Hasanbey cultivars were found to be 0.283-0.249% in 2018, 0.342-0.283% in 2019 and 0.313-0.266% in the combined averages of the two years, respectively. In both years and in the combined two-year averages, the phosphorus content values in grain measured in the İnci cultivar were found to be higher than the values measured in the Hasanbey cultivar (Table 5). [15] reported that as a result of the study conducted in 2018 and 2019, the combined average values of both years showed that Arda cultivar had a grain phosphorus content of 299.1 ppm, while Azkan cultivar had a rate of 310.7 ppm. [26] also confirmed that phosphorus fertilizers combined with organic manures and *Bacillus* inoculation improved nutrient uptake and grain quality traits, [27] stated that there were significant differences in the phosphorus content in the grain among the chickpea genotypes, and the phosphorus content values in the grain varied between 225.7-359.0 mg.

The overall phosphorus content averages obtained from vermicompost dose applications varied between 0.243-0.291% in 2018, 0.284-0.343% in 2019, and 0.263-0.317% in the combined two-year averages. While the lowest grain phosphorus content values were taken from the plots where no vermicompost was applied (0 kg ha⁻¹), the highest values were obtained from the plots where 7500 kg ha⁻¹ vermicompost was applied (Table 5). [10] reported that vermicompost and leonardite applications significantly improved macro and micro nutrient contents, including phosphorus, in chickpea grains. Similarly, [11] found that NPK combined with vermicompost enhanced growth characteristics and grain nutrient composition. [28], in their study conducted to determine the effect of organic and inorganic fertilization on yield parameters in lentil; they stated that the lowest values in terms of

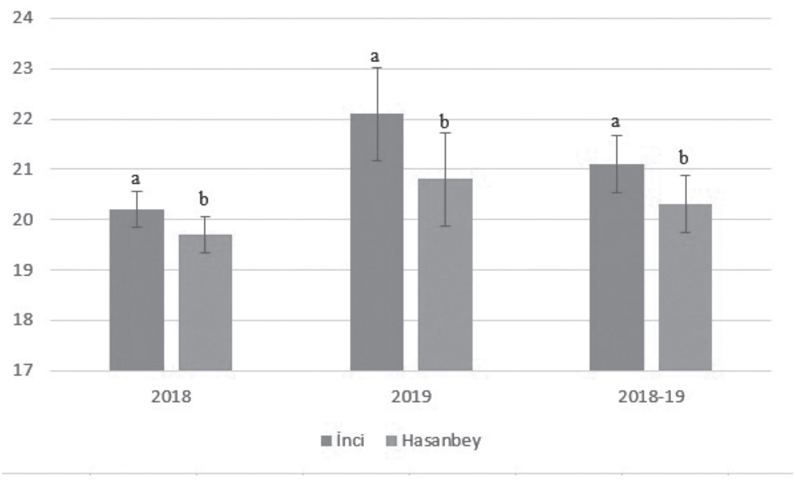

Fig. 4. Protein content (%) of İnci and Hasanbey chickpea cultivars.

Table 4. Protein content (%) in chickpea grains as influenced by microbial fertilizer and vermicompost applications.

			Microbial fertilizers / Vermicompost levels (kg ha^{-1})											
			Control				*Rhizobium*				*Bacillus*			
Traits	Year	Cultivar	0	2500	5000	7500	0	2500	5000	7500	0	2500	5000	7500
Protein content	2018	İnci	18.9	19.1	19.4	19.5	20.7	20.9	21.0	21.4	19.8	20.1	20.4	20.4
		Hasanbey	18.6	18.7	19.0	19.2	20.2	20.4	20.7	20.9	19.5	19.6	19.8	20.0
	2019	İnci	20.5	21.1	21.3	21.5	22.6	22.9	23.4	23.9	21.7	21.9	22.0	22.3
		Hasanbey	19.4	19.9	20.1	20.3	21.4	21.6	21.8	22.1	20.5	20.7	20.9	21.1
	2018-19	İnci	19.7^{lm}	21.1^{jk}	20.4^{ij}	20.5^{hi}	21.7^{cd}	21.9^{bc}	22.2^{b}	22.7^{a}	20.8^{gh}	21.0^{fg}	21.2^{ef}	21.4^{de}
		Hasanbey	18.9^{o}	19.3^{n}	19.5^{mn}	19.8^{lm}	20.8^{gh}	20.9^{fg}	21.3^{ef}	21.5^{de}	20.0^{kl}	20.2^{jk}	20.4^{ij}	20.6^{hi}
General mean			2018				2019				2018-19			
	Cultivar		20.2^{A}	19.7^{B}	-	-	22.1^{A}	20.8^{B}	-	-	21.1^{A}	20.3^{B}	-	-
	Vermicompost		19.6^{D}	19.8^{C}	20.1^{B}	20.2^{A}	21.0^{D}	21.4^{C}	21.6^{B}	21.9^{A}	20.3^{D}	20.6^{C}	20.8^{B}	21.1^{A}
	Microbial fertilizer		19.1^{C}	19.9^{B}	20.8^{A}		20.5^{C}	22.5^{A}	21.4^{B}	-	19.8^{C}	21.6^{A}	20.7^{B}	-

*Means followed by the same letter are not significantly different at $p \leq 0.05$ according to Duncan's multiple range test.

Table 5. Phosphorus content (%) in chickpea grains under microbial fertilizer and vermicompost treatments.

			Microbial fertilizers / Vermicompost levels (kg ha^{-1})											
			Control				*Rhizobium*				*Bacillus*			
Traits	Year	Cultivar	0	2500	5000	7500	0	2500	5000	7500	0	2500	5000	7500
Phosphorus content	2018	İnci	0.183^{t}	0.193^{s}	0.213^{q}	0.230^{o}	0.256^{l}	0.276^{i}	0.300^{g}	0.323^{e}	0.336^{d}	0.353^{c}	0.360^{b}	0.376^{a}
		Hasanbey	0.166^{v}	0.180^{u}	0.196^{r}	0.220^{p}	0.236^{n}	0.250^{m}	0.260^{k}	0.273j	0.280^{h}	0.300^{g}	0.303^{f}	0.323^{e}
	2019	İnci	0.206	0.223	0.236	0.256	0.300	0.316	0.350	0.376	0.426	0.456	0.473	0.486
		Hasanbey	0.173	0.193	0.203	0.233	0.253	0.263	0.290	0.310	0.346	0.360	0.383	0.396
	2018-19	İnci	0.195^{o}	0.208^{m}	0.225^{l}	0.243^{k}	0.278^{i}	0.296^{h}	0.325^{fg}	0.350^{de}	0.381^{c}	0.405^{b}	0.416^{b}	0.431^{a}
		Hasanbey	0.171^{p}	0.186^{o}	0.200^{mn}	0.226^{l}	0.245^{jk}	0.256^{j}	0.275^{i}	0.291^{h}	0.313^{g}	0.330^{f}	0.343^{e}	0.360^{d}
General mean			2018				2019				2018-19			
	Cultivar		0.283^{A}	0.249^{B}	-	-	0.342^{A}	0.283^{B}	-	-	0.313^{A}	0.266^{B}	-	-
	Vermicompost		0.243^{D}	0.258^{C}	0.272^{B}	0.291^{A}	0.284^{D}	0.302^{C}	0.322^{B}	0.343^{A}	0.263^{D}	0.280^{C}	0.297^{B}	0.317^{A}
	Microbial fertilizer		0.197^{C}	0.272^{B}	0.329^{A}	-	0.215^{C}	0.307^{B}	0.416^{A}	-	0.206^{C}	0.289^{B}	0.372^{A}	-

*Means followed by the same letter are not significantly different at $p \leq 0.05$ according to Duncan's multiple range test.

phosphorus content in grain were obtained from plots without application, followed by compost manure, and the highest phosphorus content was obtained from farm manure and 100% NPK application.

The overall average grain phosphorus values obtained from the bacterial species applied in the study ranged from 0.197-0.329% in 2018, 0.215-0.416% in 2019, and 0.206-0.372% in the combined two-year averages. The lowest values were obtained from the control plots without bacterial application, while the highest values were obtained from the *Bacillus* bacteria application (Table 5). The interaction effects of bacteria × vermicompost are illustrated in Fig. 5. [15] reported that the phosphate-solubilizing bacteria applications applied in his study positively affected grain phosphorus content. Similarly, in our study, *Bacillus* inoculation enhanced phosphorus solubilization in the rhizosphere, thereby increasing grain phosphorus content. Vermicompost further improved soil organic matter and nutrient availability, supporting root uptake and contributing to higher phosphorus accumulation in chickpea seeds.

Number of Nodules

The mean nodule number values and the corresponding group classifications for the two chickpea cultivars under different vermicompost doses and microbial fertilizer treatments are presented in Table 6.

In both years and in the combined two-year averages, the average nodule numbers obtained from İnci and Hasanbey cultivars varied between 16.9 and 15.4 in 2018, 17.2 and 16.0 in 2019, and 17.1 and 15.7 in the combined two-year averages, respectively. The average nodule number values obtained in the İnci cultivar were found to be higher than those obtained in the Hasanbey cultivar (Table 6). [29] reported in his study that the differences between the cultivars in terms of nodule number per plant were significant, and the nodule number values varied between 77.9 in Taek-Sağel cultivar and 98.3 in Diyar-95 cultivar. [13] stated that climatic factors such as rainfall and soil nitrogen dynamics strongly influence *Rhizobium* symbiosis, affecting nodulation and nitrogen fixation in chickpea, and further reported that genetic variation among chickpea cultivars leads to significant differences in nodulation potential, which is critical for sustainable productivity. [30] reported in his study that the number of nodules in chickpeas ranged from 24.6 to 54.6 per plant.

The average nodule numbers obtained from vermicompost dose applications varied between 11.3-20.0 pieces in 2018, 11.6-20.8 pieces in 2019, and 11.5-20.4 pieces in the combined two-year averages. The lowest values were obtained from plots where no vermicompost was applied (0 kg ha^{-1}), while the highest values were obtained from plots where 7500 kg ha^{-1} vermicompost was applied (Table 6). [24] reported that the highest nodule number was obtained from the chicken manure application, which is in the same group as farm manure, with 25.3 pieces/plant, and the lowest values were obtained from the 0 kg ha^{-1} (control) application with 8.9 pieces/plant.

The average nodule numbers obtained from the bacterial species applied in the study ranged from 9.0 to 20.5 in 2018, 9.3 to 19.5 in 2019, and 9.1 to 20.8 in the combined two-year averages. The lowest values were taken from the control plots, while the highest values were taken from the *Bacillus* application in 2018, and from the *Rhizobium* application in the combined 2019 and the two-year averages (Table 6). The interaction effects of bacteria × vermicompost are illustrated in Fig. 6. [31] emphasized that organic

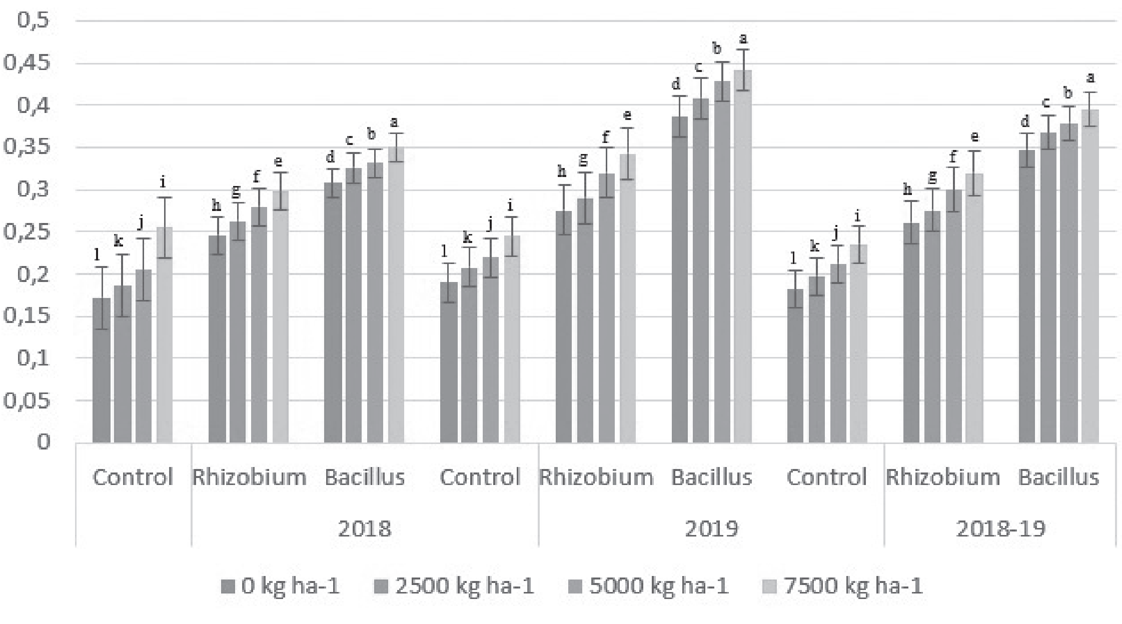

Fig. 5. Phosphorus content (%) of chickpea cultivars under microbial fertilizer treatments and vermicompost doses.

Table 6. Nodule number (plant^{-1}) of chickpea cultivars under microbial fertilizer and vermicompost treatments.

			Microbial fertilizers / Vermicompost levels (kg ha^{-1})											
			Control				*Rhizobium*				*Bacillus*			
Traits	Year	Cultivar	0	2500	5000	7500	0	2500	5000	7500	0	2500	5000	7500
Number of nodules	2018	İnci	6.1	7.6	10.7	13.6	14.7	20.4	25.7	25.3	14.4	17.2	23.9	23.9
		Hasanbey	5.3	6.5	9.6	12.7	13.9	18.1	23.1	22.7	13.9	15.9	21.8	21.8
	2019	İnci	6.1	7.8	10.8	13.8	14.9	20.7	26.0	25.5	14.7	17.6	24.0	24.9
		Hasanbey	5.7	6.9	10.0	13.1	14.2	18.7	23.3	24.9	14.4	16.2	22.2	22.5
	2018-19	İnci	6.1^{no}	7.7^{m}	10.7^{l}	13.7^{jk}	14.8^{j}	20.6^{g}	25.9^{a}	25.4^{ab}	14.5^{j}	17.4^{h}	23.9^{cd}	24.4^{bc}
		Hasanbey	5.5^{o}	6.7^{mn}	9.8^{l}	12.9^{k}	14.1^{jk}	18.4^{h}	23.2^{de}	23.8^{cd}	14.2^{j}	16.1^{i}	21.9^{f}	22.1^{ef}
General mean			2018				2019				2018-19			
	Cultivar		16.9^{A}	15.4^{B}	-	-	17.2^{A}	16.0^{B}	-	-	17.1^{A}	15.7^{B}	-	-
	Vermicompost		11.3^{D}	14.3^{C}	19.1^{B}	20.0^{A}	11.6^{D}	14.6^{C}	19.4^{B}	20.8^{A}	11.5^{D}	14.5^{C}	19.3^{B}	20.4^{A}
	Microbial fertilizer		9.0^{C}	19.1^{B}	20.5^{A}	-	9.3^{C}	21.0^{A}	19.5^{B}	-	9.1^{C}	20.8^{A}	19.3^{B}	-

*Means followed by the same letter are not significantly different at $p \leq 0.05$ according to Duncan's multiple range test.

Table 7. Nodule weight (g plant^{-1}) of chickpea cultivars under microbial fertilizer and vermicompost applications.

			Microbial fertilizers / Vermicompost levels (kg ha^{-1})											
			Control				*Rhizobium*				*Bacillus*			
Traits	Year	Cultivar	0	2500	5000	7500	0	2500	5000	7500	0	2500	5000	7500
Nodule weight	2018	İnci	0.125	0.133	0.215	0.254	0.740	1.493	1.772	1.717	0.252	0.356	0.634	0.499
		Hasanbey	0.403	0.114	0.128	0.135	0.118	1.316	1.495	1.453	0.215	0.358	0.418	0.410
	2019	İnci	0.126	0.138	0.228	0.226	0.447	1.555	1.819	1.738	0.263	0.368	0.665	0.427
		Hasanbey	0.135	0.150	0.148	0.153	0.522	1.402	1.574	1.068	0.304	0.418	0.470	0.466
	2018-19	İnci	0.126^{e}	0.136^{de}	0.222^{cde}	0.241^{cde}	0.594^{cd}	1.524^{ab}	1.795^{a}	1.728^{a}	0.258^{cde}	0.362^{cde}	0.649^{c}	0.463^{cde}
		Hasanbey	0.269^{cde}	0.132^{de}	0.138^{de}	0.144^{de}	0.292^{cde}	1.359^{ab}	1.534^{ab}	1.261^{b}	0.259^{cde}	0.388^{cde}	0.444^{cde}	0.438^{cde}
General mean			2018				2019				2018-19			
	Cultivar		0.683	0.547	-	-	0.667^{A}	0.567^{B}	-	-	0.67^{A}	0.555^{B}	-	-
	Vermicompost		0.309^{C}	0.628^{B}	0.777^{A}	0.745^{A}	0.300^{B}	0.672^{A}	0.817^{A}	0.680^{A}	0.300^{C}	0.650^{B}	0.797^{A}	0.712^{AB}
	Microbial fertilizer		0.189^{C}	1.263^{A}	0.393^{B}	-	0.163^{C}	1.266^{A}	0.423^{B}	-	0.176^{C}	1.261^{A}	0.408^{B}	-

*Means followed by the same letter are not significantly different at $p \leq 0.05$ according to Duncan's multiple range test.

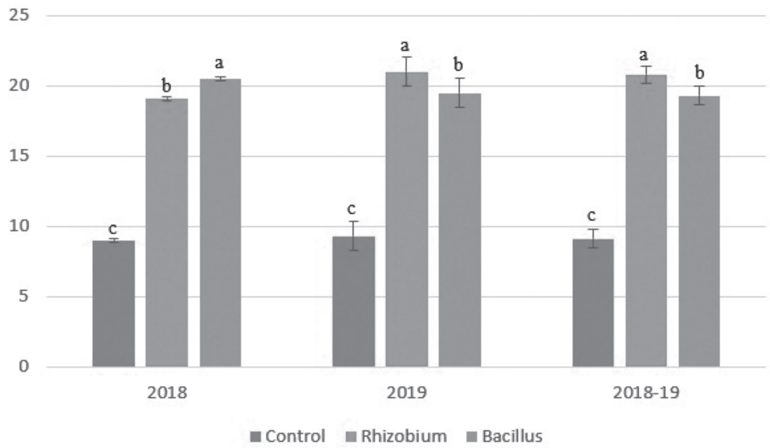

Fig. 6. Nodule number per plant of chickpea cultivars under microbial fertilizer treatments.

nutrient management practices, including *Rhizobium* inoculation and vermicompost, significantly enhanced nodulation and overall chickpea productivity. [17] stated that the maximum nodule number, 6.7, was obtained from plots where both bacteria were applied together and no phosphorus fertilizer was applied, and the lowest nodule number (4.3) was obtained from 60 kg ha^{-1} phosphorus fertilization and phosphate-solubilizing bacteria application. These findings can be explained by the enhanced symbiotic nitrogen fixation capacity of *Rhizobium*, which increases root nodulation and contributes to higher biomass accumulation under favorable soil moisture conditions. *Bacillus megaterium*, by improving phosphorus availability in the rhizosphere, indirectly supports root development and nodulation.

Nodule Weight

The mean nodule weight values and the corresponding group classifications for the two chickpea cultivars under different vermicompost doses and microbial fertilizer treatments are presented in Table 7.

In the years when the experiment was conducted and in the combined averages of the two years, the average nodule weight values obtained from İnci and Hasanbey cultivars varied between 0.683-0.247 g in 2018, 0.667-0.567 g in 2019, and 0.675-0.555 g in the combined averages of the two years, respectively. The values obtained in the first year of the study were not found to be statistically significant. In 2019 and in the combined averages of the two years, the values obtained from the İnci cultivar were higher than those from the Hasanbey cultivar (Table 7). [30] reported that the nodule dry weight varied between 0.659-1.234 g in his study. [12] reported that phosphorus fertilization combined with bacterial inoculation significantly influenced nodulation and nodule dry weight in chickpea. [13] further emphasized that symbiotic nitrogen fixation under varying climatic conditions plays a critical role in determining nodule biomass and sustainability of chickpea yield.

The overall nodule weight averages obtained from vermicompost dose applications varied between 0.309-0.777 g in 2018, 0.300-0.817 g in 2019, and 0.300-0.797 g in the combined two-year averages. The lowest values were obtained from plots where no vermicompost was applied (0 kg ha^{-1}). Although the highest values were obtained from plots where 5000 kg ha^{-1} vermicompost was applied, the differences between these and the plots where 7500 kg ha^{-1} vermicompost was applied were not found to be statistically significant (Table 7). [12] reported that phosphorus fertilization combined with bacterial inoculation significantly influenced nodulation and nodule dry weight in chickpea. [13] further emphasized that symbiotic nitrogen fixation under varying climatic conditions plays a critical role in determining nodule biomass and sustainability of chickpea yield. It can be said that the difference between the researchers' findings and our findings is due to differences in the plant's genotype, application, and ecological characteristics.

The overall average nodule weight values obtained from bacteria applications were 0.189-1.263 g in the first year, 0.163-1.266 g in the second year, and 0.176-1.261 g in the combined averages of the two years. In both years of the study and in the combined averages of the two years, the lowest values were obtained from the control plots without bacteria application, while the highest values were obtained from the *Rhizobium* bacteria application (Table 7). [17] reported that the highest nodule weight (0.27 g) was obtained from plant roots in plots applied with *Rhizobium* bacteria, while the lowest nodule weight (0.17 g) was obtained from plant roots in plots without bacteria application and only with phosphate-solubilizing bacteria application. [12] reported that phosphorus fertilization combined with *Rhizobium* and PGPR inoculation significantly increased nodule dry weight compared to control plots. [13] further emphasized that symbiotic nitrogen fixation and appropriate bacterial strains are critical for enhancing nodule biomass and sustaining chickpea yield. In our study, the higher nodule biomass observed under

Rhizobium inoculation can be attributed to effective root colonization and nitrogen fixation, while *Bacillus* inoculation likely improved phosphorus solubilization in the rhizosphere, indirectly contributing to greater nodule weight.

Conclusions

The indiscriminate use of synthetic inputs (such as fertilizers and pesticides) causes serious damage to the environment, particularly to the soil. Considering the recent increase in synthetic fertilizer consumption, this will have a significant negative impact on the country's economy. Due to the use of chemical fertilizers and pesticides, the contamination of drinking water, lasting effects on food and permanent, destructive impacts on populations of living organisms in the ecosystem are increasing day by day. Not only does it take many years to eliminate these harmful effects, but they may also lead to irreversible consequences. It is crucial to promote the use of environmentally friendly organic resources for sustainable agriculture. In this context, it is necessary to promote the use of organic fertilizer sources, increase the use of organic inputs to enable beneficial soil microorganisms to function actively, apply proper agricultural techniques, and, when necessary, compensate for any shortfalls with microbial fertilizers. These practices are important for protecting human health, other living organisms in the ecosystem, and the soil, which is the source of life. As a result, considering the soil analysis results in organic chickpea cultivation under Fethiye conditions, the application of 2500-5000 kg ha^{-1} of vermicompost and the use of microbial fertilizers in areas where planting is to be done for the first time can be recommended.

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Conflict of Interest

The authors declare no conflict of interest.

References

1. SHAH S.N., CHAUDHARI V.D., SHROFF J.C., PATEL V.J., PATEL A.P. Nutrient management through organic sources in chickpea. Legume Research, **48** (9), 1558, **2025**.
2. PELLET P. The place of chickpea and chickpea in human nutrition. Chickpea for Everyone Symposium, 29-30 September, Marmaris, pp. 37, **1988** [In Turkish].
3. SEPETOĞLU H. Edible Grain Legumes Textbook, Ege University Faculty of Agriculture Publications, İzmir, pp. 262, **2002** [In Turkish].
4. SEPETOĞLU H. Edible Grain Legumes. Ege University Faculty of Agriculture Publications, Lecture Notes: 24, İzmir, **1992** [In Turkish].
5. ERGÜN UZUNOĞULLARI R., OKUR N. Sıvı vermikompost ve mikrobiyal gübre uygulamalarının toprağın bazı kimyasal ve biyolojik özellikleri ile marul bitkisinin (*Lactuca sativa* L.) verimi üzerine etkileri. Journal of Agriculture Faculty of Ege University, **60** (2), 331, **2023** [In Turkish].
6. ÖZEL M.R., ÖKTEM A.G. Farklı düzeylerdeki vermikompost uygulamasının atdişi mısırın (*Zea mays* L. indentata) verim ve verim karakterlerine etkisi. Bitlis Eren Üniversitesi Fen Bilimleri Dergisi, **10** (4), pp. 1324, **2021** [In Turkish].
7. ANONYMOUS. Records of the Turkish State Meteorological Service, **2019** [In Turkish].
8. DÜZGÜNEŞ O., KESICI T., KOYUNCU O., GÜRBÜZ F. Araştırma ve Deneme Metotları. Anadolu Üniversitesi Ziraat Fakültesi Yayınları, 1021 Ders Kitabı, **295**, Sf.381, **1987** [In Turkish].
9. DINÇ A., TOĞAY Y. Determination of yield and some yield traits of the registered chickpea (*Cicer arietinum* L.) cultivars in Van conditions. ISPEC Journal of Agricultural Sciences, **5** (3), 544, **2021**.
10. EREN, A. Effects of different organic fertilizer compositions (Leonardite and Vermicompost) on Chickpea (*Cicer arietinum* L.) yield and macro-micro nutrient content. Legume Research, **1**, **2025**.
11. FARODA M., SUMAN B., APARNA R. Effect of NPK and vermicompost on growth characteristics and yield of chickpea (*Cicer arietinum* L.). International Journal of Research in Agronomy, **8** (9), 271, **2025**.
12. KUMAR S., MEENA R.H., SİNGH D.P., SAHARAN V., SWAMİ H. Effect of different sources of phosphorus on nutrient content and uptake by chickpea (*Cicer arietinum* L.). International Journal of Environment, Agriculture and Biotechnology, **9** (5), 241, **2024**.
13. MAHTO R.K., CHANDANA B.S., SINGH R.K., KUMAR A., KUMAR S., YADAV R., DEY D., HAMWIEH A., KUMAR R. Symbiotic nitrogen fixation for sustainable chickpea yield and prospects for genome editing in changing climatic situations. Frontiers in Plant Science, **16**,1621191, **2025**.
14. GIMENEZ R., LAKE L., COSSANI C.M., MARTINEZ R.O., HAYES J.E., DRECCER M.F., FRENCH R., WELLER J.L., SADRAS V.O. Linking phenology, harvest index, and genetics to improve chickpea grain yield. Journal of Experimental Botany, **76** (6), 1658, **2025**.
15. DOĞAN S., ÇIĞ F. Effects of chemical, organic and microbial fertilization on agronomical growth parameters, seed yield and chemical composition of chickpea. Journal of Elementology, **28** (4), 949, **2023**.
16. ALDEMIR B. Nohut (*Cicer arietinum* L.) tarımında gül posası, ahır gübresi ve aşılamanın verim ve bazı verim öğelerine etkileri (yüksek lisans tezi). IUBÜ, Lisans Üstü Eğitim Enstitüsü, Isparta, **2019** [In Turkish].
17. ÜYETÜRK A.S., KAYAN N., TOĞAY N. Effects of different soil tillage methods, phosphorus fertilizer doses and bacteria inoculation on yield and yield traits in chickpea (*Cicer arietinum* L.). Romanian Agricultural Research, **40**, 317, **2023**.
18. TANDAN V., KESHRY P.K., SAO Y., NIRMALKAR V.K., CHAURE N.K. Impact of different Rhizobium isolates on yield attributes, yield and post-harvest soil available nitrogen in chickpea (*Cicer arietinum* L.).

International Journal of Advanced Biochemistry Research, **9** (8S),792, **2025**.

19. AMIN A.M., MOGHADASI M.S. The interaction effect of nitrogen and vermicompost on chickpea yield and yield traits in Hamedanregion. Biological Forum- An International Journal, **7** (2), 812, **2015**.
20. GUNTIMADUGU R.K.S., SANDEEP M., KUMAR A.K., BURRA S., JAYANTHI J. Effect of organic manures and biofertilizers on productivity and profitability of wheat + chickpea intercropping system. Indian Journal of Agricultural Research, **59**, 83, **2025**.
21. SHIV T.S., NIVEDITA S. Yield and yield attributes of chickpea as influenced by phosphorus and bio-fertilizer application under Rainfed conditions. Legume Research, **48** (2), 312, **2025**.
22. NABATI J., NEZAMI A., YOUSEFI A., OSKOUEIAN E., OSKOUEIAN A., AHMADI-LAHIJANI M.J. Biofertilizers containing plant growth promoting rhizobacteria enhance nutrient uptake and improve the growth and yield of chickpea plants in an arid environment. Scientific Reports, **15**, 8331, **2025**.
23. SOFI S.O., TALABANI S.K., SLEMAN S.M., FARAJ S.H.G., HALSHOY H.S. Impact of bio-based and synthetic phosphorus application on growth, yield, and protein profile of two chickpea genotypes. Agricultural Research, **14**, 97, **2025**.
24. ALTINKAYNAK C., TOĞAY N. The effects of yield, quality and environment of rhizobium inoculation, organic and inorganic manures sources on chickpea (*Cicer arietinum* L.). Bacterial Practices in Agriculture, Fatih Çığ, Chapter 10, page-277: Iksad Publications, **2021**.
25. ÖZKÖSE A. Contribution of legume-derived biological nitrogen fixation in reducing greenhouse gas emissions originating from agriculture in Türkiye. Polish Journal of Environmental Studies, **33** (2), 1337, **2024**.
26. KHAN M.I., AFZAL M.J., BASHIR S., NAVEED M., ANUM S., CHEEMA S.A., WAKEEL A., SANAULLAH M., ALI M.H., CHEN Z. Improving nutrient uptake, growth, yield and protein content in chickpea by the co-addition of phosphorus fertilizers, organic manures, and *Bacillus* sp. MN-54. Agronomy, **11** (3), 436, **2021**.
27. BAYRAK H., ÖNDER M. Determination of agronomic, technological, and nutritional characteristics of local chickpea populations and cultivars (*Cicer arietinum* L.) cultivated in Konya ecological region. Journal of Field Crops Central Research Institute, **26** (Special Issue), 52, **2017** [In Turkish].
28. SAKET S., SINGH S.B., NAMDEO K.N., PARIHA S.S. Effect of organic and inorganic fertilizers on yield, quality and nutrients uptake of lentil. Annals of Plant and Soil Research, **16** (3), 238, **2014**.
29. EKER S. Bazı nohut çeşitlerinde farklı gübre uygulamalarının verim ve verim unsurlarına etkisi (yüksek lisans tezi). Dicle Üniversitesi, Fen Bilimleri Enstitüsü, Diyarbakır, **2019** [In Turkish].
30. UÇAR Ö., ERMAN M. Farklı sıra arası mesafeleri, tavuk gübresi dozları ve tohum ön uygulamalarının nohut (*Cicer arietinum* L.)'un verim ve verim özellikleri üzerine etkileri. ISPEC Tarım Bilimleri Dergisi. **4** (4), 875, **2020** [In Turkish].
31. VERMA M., MISHRA B.K., NATH A., SINGH R., TRIPATHI A.K., KUMAR S. Enhancing productivity and profitability of chickpea (*Cicer arietinum* L.) through organic nutrient management under Indo-Gangetic plains conditions. International Journal of Research in Agronomy, **8** (7), 1307, **2025**.