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ORIGINAL PAPER

Effects of chemical, organic and microbial fertilization on agronomical growth parameters, seed yield and chemical composition of chickpea*

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Abstract

Because of its valuable nutritional content, chickpea is expected to become the most important crop for the increasingly larger global population. Therefore, this research was carried out in 2018 and 2019 to investigate the effects of microbial (*Bacillus-GC group*, *Pseudomonas tetraodonis* and *Brevibacillus choshinensis*), organic (vermicompost and chicken manure) and chemical (DAP/2 ve DAP) fertilizer applications on yield and nutritient content of two different chickpea cultivars (Arda and Azkan). The experiment was laid out according to a randomized complete split-block design with three replications. The results expressed as the average values of two-year experiments projected that the application of chicken manure significantly improved the morphological traits of chickpea plants compared to the other treatments, while the highest phosphorus content was recorded after the application of farm manure. Additionally, the highest grain yield from both cultivars was obtained owing to the application of chicken manure. Apart from this effect, other microbial applications also played a positive role in plant growth and production, but chicken manure excelled in this respect. Thus, it has been concluded that chicken manure could be used as a suitable alternative to chemical fertilizer for chickpea cultivation in order to create a sustainable agricultural system, increase productivity and protect and improve soil properties.

Keywords: chemical fertilizer, chicken manure, microbial fertilizer, organic fertilizer, sustainable agriculture

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INTRODUCTION

Edible legumes, whose consumption dates back approximately 8-10 thousand years ago, have an important place in human nutrition. Chickpea, widely used in human nutrition, contains 18-30% protein. It is rich in vitamin and fiber content, and very rich in potassium, zinc, calcium, magnesium and iron (Güler et al. 2001). Legumes are also an important source of amino acids that cannot be synthesized by humans, and 8 of these amino acids (isoleucine, lysine, leucine, methionine, phenylalanine, threonine, tryptophan and valine) must be taken daily (Keskin et al. 2021). Being rich in protein but low in cellulose, the stems of legumes are significant in animal nutrition. Legumes have the important capability of fixing atmospheric nitrogen in the areas where they are grown (Ahmad et al. 2022). This nitrogen amount they can absorb is around 5-20 kg da^{-1} per year, depending on the plant type and environmental conditions (Kantar et al. 2007). In addition to enriching the soil in which edible legumes are planted with organic matter, these plants improve the heating, aeration and water-holding capacity of the soil. Plant nutrition is an important factor increasing the yield and quality of plants. Although the usage of commercial fertilizer in Turkey is not higher than in advanced countries, many wrong fertilization practices disrupt the soil structure and cause damage to ecology and living organisms (Savci 2012). For these reasons, interest in the use of nitrogen-fixing and phosphate-solubilizing microorganisms as microbial fertilizers is increasing constantly.

The main mechanism of microorganisms promoting plant growth is through nitrogen fixation and increasing nutrient uptake by organic-inorganic phosphate solubilization. When suitable bacteria such as nitrogen fixers or phosphate solubilizers are used, microorganisms facilitate the uptake of inorganic fertilizers by plants (Glick 2020). Microbial fertilizer is a new solution that has a positive effect on crop yield and quality (Kovacs et al. 2012). In this respect, the use of microbial fertilizers is very important in terms of plant nutrition and cost reduction (Khan et al. 2007). The key role of organic fertilizers is to maintain soil biodiversity and soil aggregate stability (Gleń-Karolczyk et al. 2018). Farm manure is an important alternative to mineral fertilizers. It has a positive effect on the physical, chemical and biological structure of the soil. It is very important in terms of increasing the amount of organic matter in the soil. Organic amendments enhance soil pH and water-holding capacity of the soil by improving the microbial activity, increasing aeration, and altering the chemical composition, thereby they promote the nutrient uptake by plant roots (Werner 1997, Ceritoglu et al. 2018, Bice Ataklı et al. 2022). Chicken manure contains much of macro- and micronutrients. Therefore, it provides remarkable amounts of nutrients in soil for plant growth. However, when applied at excessive levels, various salts can accumulate in the soil and have a toxic effect on the grown plants (Shapovalov et al. 2020). Vermicompost is the excrement of some earthworms, which convert many organic materials into rich-content organic fertilizer (Şahin, Ceritoglu, 2020). It does not contain any chemical compounds that adversely affect the health of living organisms, weed seeds or toxic elements (Gudeta et al. 2022). Vermicompost is known to promote plant growth and productivity owing to its content of nutrients and various metabolites, and to protect plants against biotic and abiotic stress factors, such as salinity, drought, pathogens, etc. (Ceritoglu, Erman, 2020*a*, Makkar et al. 2023). This study aimed to evaluate the efficiency of microbial and organic fertilizers compared to chemical fertilizers on the growth and productivity of chickpea crops, as well as their ability to return waste organic materials to agricultural soils and to promote the recycling of elements.

MATERIALS AND METHOD

Experimental materials

Most extensively cultivated chickpea varieties (Arda & Azkan) were selected as plant material in the study. Three different groups of fertilizers, including chemical (Diammonium phosphate), microbial (*Bacillus-GC group*, *Pseudomonas tetraodonis* and *Brevibacillus choshinensis*) and organic fertilizers (chicken manure, vermicompost and farm manure), were selected as fertilizers. Pre-sowing fertilizer samples were taken from the trial areas and analyzed in the laboratory of Mardin Artuklu University Research Center. The chemical properties of organic manures were given in Table 1.

Diammonium phosphate (DAP) is a composite fertilizer containing two important plant nutrients, phosphate and nitrogen. *Pseudomonas tetraodonis* (TV126C), *Bacillus*-GC (TV119E) and *Brevibacillus choshinensis* (TV53D)

Table 1

Some chemical properties of organic fertilizers used in the research

Characteristics	Chicken	Farm Manure	Vermicompost
Organic matter (%)	56.27	46.20	49.60
Nitrogen (%)	3.64	2.85	2.12
Phosphorus (P_2O_5) (%)	1.63	1.65	1.21
Potassium (K_2O) (%)	1.38	1.35	1.60
Organic carbon (%)	33.63	27.33	26.20
pH	6.82	7.03	7.40
Humidity (%)	9.2	10.8	12.6
Iron (ppm)	2428	-	0.56
Zinc (ppm)	412	-	4,60
Copper (ppm)	33.72	-	0.60
Manganese (ppm)	673	213	0.05

were selected as a nitrogen fixer, phosphate solubilizer and nitrogen fixer+-phosphate solubilizer, respectively. Bacterial strains were isolated from the Van Lake basin and diagnosed by the MIS system in 2010. Detailed information regarding bacteria was given in Table 2.

Table 2

Information on the bacteria used in the research

Code	No	Mis Diagnosis Result	Location	Host	N	P
TV	119E	*Bacillus-GC group*	Ulupamir Köyü/Van	-	W	+
TV	126C	*Pseudomonas tetraodonis*	Ulupamir Köyü/Van	wheat-Tir	S	W
TV	53D	*Brevibacillus choshinensis*	Çakirbey Köyü/Van	Taraxacum	S	S

W – Weak, S – Strong, (+) Positive

Research location and metrological information

The province of Mardin, where the research was conducted, is in the Southeastern Anatolia Region. The province lies at an altitude of 1150 m, and at 37° 18′ north latitude and 40° 44′ east longitude.

The meteorological data of Mardin, where the experiment was carried out, both for the months covering the plant's growing season and the long-term averages (LTA), were given in Table 3. In the years when the study was conducted, the total precipitation of the region, as an LTA, was 449.1 mm, the average temperature was 12.3°C, and the average relative humidity was 55.3%. The amount of precipitation recorded in the growing season of the first year in which the study was conducted was 447.3 mm, the average temp. in the same period was 14.9°C, and the average relative humidity was 52.6%. While the total precipitation and average temperature data of the growing season were higher than the long-term average data, the relative

Table 3

Some climate data for 2018, 2019 and the long-term average (LTA) for the plant growing period in Mardin province (MGT, 2019)

Months	Average temperature (°C)			Precipitation (mm)			Humidity (%)		
	2018	2019	LTA	2018	2019	LTA	2018	2019	LTA
January	5.7	3.7	3.1	58.7	116.3	116.7	66.8	78.0	70.0
February	8.0	5.9	4.2	91.8	90.5	103.7	67.1	68.1	66.0
March	13.0	7.5	8.0	8.7	147.8	96.4	54.1	72.9	61.0
April	16.7	11.1	13.5	32.5	138.7	82.0	41.6	69.2	56.0
May	19.6	21.7	19.5	221.7	34.2	45.8	54.0	38.2	45.0
June	26.2	29.7	25.7	33.9	0.0	4.5	32.3	22.2	34.0
Total	89.2	79.6	73.9	447.3	527.5	449.1	315.9	348.6	332.0
Average	14.9	13.3	12.3	74.6	87.9	74.8	52,6	58.1	55.3

humidity was below the long-term average. In the second year, the average temperature, precipitation and relative humidity were higher than the long-term averages. In 2018, February, March and April were dry and hot, and May was rainy. In 2019, February, March, and April were rainy and May was dry and hot.

Soil characteristics of the research site

According to the analysis, the soil of experimental area is flat and nearly flat deep soils with alluvial parent material. It has a clay-loam (CL) texture as determined by the Bouyoucus hydrometric method. The soil of the experiment area was found to be calcareous according to the calcimetric method, was slightly alkaline (Horneck et al. 1989), and had a low organic matter content (Diaz-Zorita et al. 1999). Sufficient potassium content and moderate phosphorus content were determined with the flame photometric method (Steward, Ruzicka, 1976) and spectrophotometric method (More 1992), respectively (Table 4).

Table 4

Some physical and chemical properties of the soils of the research area

Depth (cm)	Texture	Sand (%)	Silt (%)	Clay (%)	pH	EC (%)	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Organic matter (%)
0-30	CL	39.3	27.7	33.1	8.1	0.032	156	366	1.36

CL – Clay-loam)

Layout of the experiment

The experiment carried out in Mardin was established according to a Trial Design of Divided Plots in Random Blocks with three replications. The trial plot was 4 m long, 1 m wide and comprised five rows of plants. The distance between the trial plots was 1 m, and the distance between the blocks was 2 m. The sowing density was 55 seeds per square meter. Two chickpea cultivars (Azkan and Arda) were used in the experiment. As inorganic fertilizer applications, 100% (30 kg N + 50 kg P ha^{-1}) and 50% of DAP (15 kg N + 25 kg P ha^{-1}) were given to inorganically fertilized plots. Chicken manure, vermicompost and farm manure were applied at doses of 3, 4 and 20 tonnes ha^{-1}, respectively (Table 5). The experiment was laid out according to a randomized complete split block design with three replications. Cultivars composed main plots, and fertilizer applications were placed in sub-plots. The field experiments were repeated for two years. The experiment was started on 01.03.2018 in the first year, and on 13.03.2019 in the second year. DAP manure, vermicompost, chicken manure and farm manure were applied to the experimental plots by spreading them on the soil before planting, and mixing with the soil with a rake. In the experiment, weed control was done mechanically twice, before and after flowering. Since there was no disease

Table 5

Application doses of various groups of fertilizers in chickpea crop

Applications	Amounts
Control	no fertilizer
DAP	140 kg ha^{-1}
DAP/2	70 kg ha^{-1}
Chicken manure	4 tonnes ha^{-1}
Vermicompost	3 tonnes ha^{-1}
Farm manure	20 tonnes ha^{-1}
TV126C	2.2 - 8.8 x 10^{8} cfu mL^{-1}
TV119E	2.2 - 8.8 x 10^{8} cfu mL^{-1}
TV53D	2.2 - 8.8 x 10^{8} cfu mL^{-1}

or pest detected, no chemical control was needed. For the measurements, one row on the edges of each plot and 0.5 m sections from the plot fronts were excluded as edge effects, and 10 plants were obtained from randomly selected areas of 0.6 m x 4 m = 2.4 m^2 in 20 cm row spacing.

Observation of agronomical characteristics, yield and quality attributes

Before harvest, plant height was determined on ten randomly selected plants from each plot. After harvest, the biological yield was determined and grains were separated from the straw. Number of pods per plant, number of grains per plants, grain yield and 100-grain weight were determined to investigate yield attributes. Grain protein ratio, phosphorus content and potassium content were determined to observe quality attributes. Grain protein ratio was determined with the Kjeldahl method (Horwitz, Latimer 2006). Phosphorus and potassium contents were analyzed with the spectrophotometric ISP-OES (Olsen et al. 1954) and flame photometric (Ashutosh et al. 2022) methods, respectively.

Statistical analysis

Analysis of variance (ANOVA) test was applied to data in the JMP (v5.0.1) statistics program. The data were grouped by the Least Significant Difference (LSD) test.

RESULTS AND DISCUSSION

The results of the variance analysis of the impact of microbial, organic and inorganic fertilizer applications on 2 different chickpea cultivars in 2018 and 2019 are given in Table 4.1. The effect of different groups of fertilizer (treatments) on plant height, number of pods, biological yield and number of seeds on cultivar and statistically significant effects of treatments were observed at the level of 1% in 2018 and 2019, while the interaction of cultivar × fertilizer treatments was found to be non-significant. The effect of cultivars was significant at 1% in terms of 100-grain weight, and the interactions of fertilizer treatments and cultivar × treatment were non-significant. Additionally, the cultivar as a factor was important in terms of grain yield in 2018 and 2019, the treatment was significant in 2018 and 2019, and the interaction of cultivar × treatment was non-significant. The Harvest Index of treatments attained important values. While the effect of the variety and treatment was statistically significant at the level of 1% in terms of the protein ratio and phosphorus content, the cultivar × treatment interaction was found to be non-significant in 2018. The potassium content was non-significant (Table 6).

Table 6

The variance analysis of the effects of microbial, organic fertilizer and inorganic fertilizers on the investigated properties in chickpea plant

Specification	Varieties		Applications		V x A interactions	
	2018	2019	2018	2019	2018	2019
Plant height	134.87**	124.33**	33.58**	11.28**	0.75	2.24
Number of pods	17.01**	29.04**	8.49**	6.84**	0.99	0.79
Number of grains per plant	20.14**	24.01**	8.08**	7.83**	1.16	0.22
100 Grain weight	263.65*	626.94*	1.25	2.14	1.95	1.12
Grain yield	107.52**	46.59**	23.61**	30.04	1.42	0.54**
Biological yield	135.10**	54.15**	6.08**	4.53**	0.59	0.80
Harvest index	0.65	2.49	14.30**	8.74**	0.94	0.28
Protein ratio	679.59**	301.04**	55.63**	21.84**	5.06	2.80*
Phosphorus content	194.90**	175.95**	79.73**	89.58**	1.55	2.98*
Potassium content	3.64	1.77	1.31	0.47	0.89*	0.93*

* $p<0.01$, ** $p<0.05$

Plant height

In Table 7, average values of plant height in 2018 were measured as 58.2-63.8 cm. Among the treatments, the plant height varied between 53.2-68.8 cm, the lowest plant height value was obtained from the control plots, while the highest plant height of 68.8 cm was detected after the chicken manure application. In 2019, plant height values were measured as 48.0-56.2 cm. In terms of applications, the plant height varied between 44.6-57.9 cm, the lowest was obtained in the control plots, while the highest of 57.9 cm was obtained after the application of chicken manure with.

Table 7

Average values and significance groups showing the effect of microbial, organic fertilizer and inorganic fertilizers on plant height (cm) in chickpea plant

Applications	2018 years			2019 years			Variety x applications		Mean
	Arda	Azkan	mean	Arda	Azkan	mean	Arda	Azkan	
Control	55.2*hi*	51.1*j*	53.2*E*	46.6*ij*	42.6*j*	44.6*E*	50.9	46.9	55.2*hi*
DAP/2	62.7*de*	54.8*i*	58.8*D*	51.8*eg*	48.0*gi*	49.9*D*	57.3	51.4	62.7*de*
DAP	63.3*ce*	59.1*fg*	61.2*C*	55.4*ce*	49.4*fi*	52.4*BD*	59.3	54.2	63.3*ce*
Chicken manure	71.7*a*	65.8*bc*	68.8*A*	62.8*a*	52.9*df*	57.9*A*	67.3	59.4	71.7*a*
Vermicompost	64.1*cd*	59.3*fg*	61.7*C*	56.4*bd*	46.9*hj*	51.6*BD*	60.3	53.1	64.1*cd*
Farm manure	67.4*b*	60.7*ef*	64.0*B*	58.0*bc*	51.2*eh*	54.6*B*	62.7	55.9	67.4*b*
TV126C	63.6*cd*	57.5*gi*	60.6*CD*	55.3*ce*	46.8*hj*	51.1*CD*	59.5	52.2	63.6*cd*
TV119E	63.5*ce*	58.2*fg*	60.9*CD*	59.0*ac*	47.0*hi*	53.0*BD*	61.2	52.6	63.5*ce*
TV53D	62.9*ce*	58.1*fh*	60.5*CD*	60.8*ab*	46.9*hj*	53.8*BC*	61.8	52.5	62.9*ce*
Mean	63.8 *A*	58.2 *B*	61.1 *A*	56.2 *C*	48.0 *D*	52.1 *B*	60.0 *A*	53.1 *B*	63.8 *A*
CV (%)	2.86			5.09			3.94		

In the combined analysis, it is seen that the Arda variety with a plant height of 60.0 cm is taller than Azkan (53.1 cm). While the plant height varied between 48.9-63.3 cm as the general average of the applications, the lowest plant height was obtained from the control plots, while the highest plant height (63.3 cm) was measured in the chicken manure treatment.

The difference in year-average plant heights is due to the different climatic characteristics of the years, especially the difference in the amount of precipitation recorded during the development period of the plant each year. Bell *et al.* (2011) found plant height between 32.6-45.7 cm. Differences in results are thought to be caused by the ecological factors of the region, variety of cultivars and climatic factors. Biçer and Şakar (2008) reported that chickpea plant height is a character that is significantly affected by environmental factors. Elkoca et al. (2008) reported that the highest plant height was obtained from NP application and microbial inoculation. Amin and Moghadasi (2015) indicated that plant height was higher in nitrogen and vermicompost treated plants compared with control group. Yeşirbaş (2015) reported that chicken manure promoted plant height over control in chickpea plants. On the other hand, Zeidan (2007) stated that organic fertilizers increase plant height, while Janmohammadi et al. (2015) reported that farm manure promotes plant height more than foliar manure.

Number of pods per plant

When Table 8 is examined, it is seen that the number of pods per plant varied from 20.4 to 32.8, and the highest pod number was 32.8, obtained

Table 8

Average values of the number of pods per plant following the application of microbial, organic fertilizer and inorganic fertilizers in chickpea plant cultivation

Applications	2018 years			2019 years			Variety x applications		Mean
	Arda	Azkan	mean	Arda	Azkan	mean	Arda	Azkan	
Control	23.4	17.5	20.4*d*	19.0	16.6	17.8 *d*	21.2	17.0	19.1 *D*
DAP/2	26.6	20.5	23.6*cd*	23.5	19.4	21.4 *c*	25.0	20.0	22.5 *C*
DAP	29.9	24.5	27.2*b*	28.9	22.4	25.7*ab*	29.4	23.5	26.4 *B*
Chicken manure	33.0	32.7	32.8*a*	33.0	24.2	28.6*a*	33.0	28.4	30.7 *A*
Vermicompost	28.2	24.0	26.1*bc*	26.5	24.0	25.3*ab*	27.4	24.0	25.7 *B*
Farm manure	29.7	27.1	28.4*b*	28.1	25.2	26.7*ab*	28.9	26.1	27.5 *B*
TV126C	28.8	26.4	27.6*b*	26.6	23.1	24.8*bc*	27.7	24.7	26.2 *B*
TV119E	27.2	25.4	26.3*bc*	26.8	23.1	24.9*ac*	27.0	24.2	25.6 *B*
TV53D	27.2	27.3	27.2*b*	27.8	22.4	25.1*ab*	27.5	24.8	26.2 *B*
Mean	28.2*A*	26.7 *B*	26.6	25.0 *A*	22.3 *B*	24.5	27.5 *A*	23.6 *B*	
CV (%)	10.68			8.92			11.29		

after the chicken manure application while the lowest pod number was harvested from the control plots. In the first year, the Arda cultivar had a higher pod number at 28.2 per plant than Azkan cultivar (26.6). In the second year, the number of pods varied between 17.8 and 28.6, and – same as in the first year – the lowest pod numbers were obtained from the chicken manure application. When the combined average values of both years were examined, they reached 27.5 for the Arda variety and 23.6 for the Azkan variety. While the lowest number of pods was obtained from the control plots, the highest number of pods (32.7) was obtained from the chicken manure application.

Kaya et al. (2008) investigated the effect of organic and commercial fertilizers on chickpea plants, and indicated that the lowest number of pods per plant was obtained from control plots (11.7), followed by commercial fertilizer application (15.2) and organic fertilizers. Elkoca et al. (2008) studied microbial and chemical fertilizer applications in chickpeas, and reported that the lowest number of pods per plant was in non-treated plots, followed by those treated with microbial fertilizer. The lowest number of pods per plant was determined in chemically fertilized plots. Amin and Moghadasi (2015) reported that vermicompost and nitrogen fertilization increased the number of pods per plant in chickpea plants. Saket et al. (2014) stated that the highest number of pods per plant was obtained from farm manure application, while Zeidan (2007) stated that as the amount of organic fertilizer applied increased, the number of pods per plant increased. The results are in agreement with the previous experiment except for differences due to climatic conditions.

Number of grains per plant

According to Table 9, 29.7 grains were obtained from the Arda variety and 26.2 from the Azkan variety in 2018. In the same year, the number of seeds per plant varied between 21.6-33.1, and the lowest number of pods

Table 9

Average values of the number of grains per plant in chickpea plants after the application of microbial, organic fertilizers and inorganic fertilizers

Applications	2018 years			2019 years			Variety x applications		Mean
	Arda	Azkan	mean	Arda	Azkan	mean	Arda	Azkan	
Control	24.1	19.1	21.6*d*	20.7	17.7	19.2*d*	22.4	18.4	20.4*D*
DAP/2	27.5	22.7	25.1*c*	24.7	20.7	22.7*cd*	26.1	21.7	23.9*C*
DAP	34.4	25.8	30.1*ab*	30.0	23.8	26.9*b*	32.2	24.8	28.5*B*
Chicken manure	34.3	31.9	33.1*a*	34.2	29.4	31.8*a*	34.2	30.6	32.4*A*
Vermicompost	29.3	25.6	27.5*bc*	28.1	25.0	26.5*b*	28.7	25.3	27.0*B*
Farm manure	30.8	29.2	30.0*ab*	29.1	26.2	27.6*b*	29.9	27.7	28.8*B*
TV126C	29.5	27.3	28.4*b*	27.9	24.3	26.1*bc*	28.7	25.8	27.2*B*
TV119E	28.7	26.7	27.7*bc*	28.2	24.2	26.2*bc*	28.5	25.5	27.0*B*
TV53D	28.4	28.0	28.2*bc*	29.0	23.5	26.2*bc*	28.7	25.8	27.2*B*
Mean	29.7*A*	26.2*B*	28.0	28.0*B*	23.9*A*	25.9	28.5*A*	25.1*B*	
CV (%)	10.02			11.60			10.77		

was obtained from the control plots, while the highest number of grains was obtained from the chicken manure application. In 2019, the number of seeds per plant was the highest in the Arda variety (28.0) and the lowest in the Azkan variety (23.9). In the applications, the number of grains per plant varied between 19.2-31.8, and the lowest value was obtained in the control plots, while the highest value was obtained from the application of DAP. In the study, when the results obtained from the combined analyses of both years in terms of the number of grains per plant were examined, it was found that 25.1 grains were obtained in the Azkan variety and 28.5 grains in the Arda variety. The lowest number of pods was obtained from the control plots, and the highest number of pods (32.4) was obtained from the DAP application.

The genetic structure of the variety, environmental conditions and applied cultivation techniques are effective in completing the development of the chickpea plant and obtaining a high yield per unit area. There is a positive and reliable relationship between the number of seeds and pods per plant and grain yield. Increasing the number of grains and pods in the plant also increases the grain yield in the plant (Erman et al. 1997, Ceritoglu, Erman 2020*b*). In our study, varieties and applications showed superiority in terms of the number of pods and number of seeds in the plant. The results are in agreement with the findings of Toğay et al. (2005). Kaya et al. (2008) indicated that the lowest number of grain per plant was determined in non-treated plots (14.3 units), while the highest one (19.9) was observed in organic fertilized plants. Amin and Moghadasi (2015) stated that vermicompost and nitrogen fertilization promoted the number of grains per plant in the chickpea growing areas. Yeşirbaş (2015) reported that chicken manure is more effective in increasing the number of grains per plant in chickpea compared with DAP and sheep manure. The findings achieved in our study are highly similar to the findings obtained by many researchers in different places and with different plants. The number of grains in the plant, which is a quantitative character, is not only directly related to the number of pods in the plant, but also significantly affected by the climate and soil conditions.

100-grain weight

When Table 10 is analyzed, this trait varied between 31.2-33.7 g in 2018. In the same year, the hundred-grain weight varied between 32.0-32.9 g in the applications, and the effect of the applications on the hundred-grain weight was insignificant, although the lowest hundred-grain weight was obtained from the control plots, while the highest hundred-grain weight was obtained from the chicken manure application. In 2019, the Azkan variety had a higher hundred-grain weight of 35.3 g compared to the Arda variety (32.0). In the applications, 100-grain weights varied between 33.1-34.1 g, and the lowest value was weighed in the control plots in the first

Table 10

Average values of 100-grain weight of chickpea plant grains after the application of microbial, organic fertilizer and inorganic fertilizers

Applications	2018 years			2019 years			Variety x applications		Mean
	Arda	Azkan	mean	Arda	Azkan	mean	Arda	Azkan	
Control	30.8	33.3	32.0	31.9	34.9	33.4	31.3	34.1	32.7*C*
DAP/2	31.5	33.8	32.7	32.1	35.3	33.7	31.8	34.6	33.2*AB*
DAP	31.6	33.8	32.7	32.2	35.5	33.9	31.9	34.7	33.3*AB*
Chicken manure	31.7	34.0	32.9	32.5	35.7	34.1	32.1	34.9	33.5*A*
Vermicompost	31.3	33.5	32.4	31.8	35.2	33.5	31.6	34.4	33.0*BC*
Farm manure	31.1	33.7	32.4	32.3	35.0	33.7	31.7	34.4	33.0*BC*
TV126C	30.7	33.7	32.2	31.1	35.4	33.3	30.9	34.5	32.7*C*
TV119E	30.6	34.5	32.6	31.7	34.9	33.3	31.2	34.7	32.9*BC*
TV53D	31.6	33.1	32.3	32.2	35.3	33.8	31.9	34.2	33.0*AC*
Mean	31.2*D*	33.7*B*	32.5*B*	32.0*C*	35.3*A*	33.6*A*	31.6*B*	34.5*A*	
CV (%)	1.74			1.38			1.57		

year, while the highest 100-grain weight was weighed in the chicken manure application. In the combined analysis of both years in the study, the average of both years was 33.6 g for the Azkan variety, which was higher than the 100-grain weight for the Arda variety (32.6 g). The effect of different applications on the 100-grain weight is significant, although the lowest hundred-grain weight was obtained from the control plots, and the highest 100-grain weight was obtained from the chicken manure application.

The 100-grain weight decreases were due to the high rainfall during the flowering period, the increase in the number of cloudy days and the high temperature. In this context, high precipitation during the flowering period and the number of cloudy days in the second year of the research delayed flowering and pod setting. Moreover, althought climatic and agronomic factors affect the grain size, this attribute is mainly controlled by genetic traits, therefore, differences between cultivars in grain size are a predictable phenomenon (Toğay et al. 2005, Doğan 2015).

Grain yield

Table 11 showed a higher yield of 2276 kg ha^{-1} obtained by the Arda variety compared to the Azkan variety (2045 kg ha^{-1}) in 2018. In the same year, the grain yield ranged between 1833-2431 kg ha^{-1}, the lowest grain yield was obtained from the control plots, while the highest grain yield (2431 kg ha^{-1}) was obtained from the chicken manure application. In the second year, 2037 kg ha^{-1} grain yield was obtained from the Arda variety and 1915 kg ha^{-1} grain yield from the Azkan variety. Grain yield from the fertilizer applications

Table 11

Average values of grain yield from chickpea plants after the application of microbial, organic fertilizer and inorganic fertilizers

Applications	2018 years			2019 years			Variety x applications		Mean
	Arda	Azkan	mean	Arda	Azkan	mean	Arda	Azkan	
Control	1938	1729	1833*e*	1756	1693	1724*e*	1847	1711	1779*F*
DAP/2	2217	1862	2040*d*	1882	1794	1838*d*	2050	1828	1939*E*
DAP	2364	2013	2189*bc*	2023	1924	1973*bc*	2194	1968	2081*CD*
Chicken manure	2562	2301	2431*a*	2304	2181	2243*a*	2433	2241	2337*A*
Vermicompost	2310	2140	2225*b*	2126	1960	2043*b*	2218	2050	2134B*C*
Farm manure	2344	2166	2255*b*	2099	1990	2045*b*	2221	2078	2150B
TV126C	2247	2119	2183*bc*	2092	1905	1999*bc*	2170	2012	2091B*D*
TV119E	2287	2043	2165*bc*	2006	1865	1936 *c*	2147	1954	2050*D*
TV53D	2212	2029	2121*cd*	2047	1919	1983*bc*	2130	1974	2052 *D*
Mean	2276*A*	2045B	2160*A*	2037B	1915*C*	1976B	2156*A*	1980B	
CV (%)	3.78			3.74			3.56		

varied between 1724-2243 kg ha^{-1}, the lowest grain yield was obtained from the control plots, and the highest grain yield was obtained from the chicken manure application. When the combined results of the two years were examined, a higher grain yield was obtained from the Arda variety (2156 kg ha^{-1}) compared to the Azkan variety (1980 kg ha^{-1}). The effect of different applications on the grain yield is significant; the lowest grain yield (1779 kg ha^{-1}) was obtained from the control plots, followed by the DAP/2 application. The highest grain yield was obtained from chicken manure application (2337 kg ha^{-1}), followed by farm manure, while the other applications resulted in similar grain yields.

It is thought that the difference between the years in terms of grain yield is due to the climate data between 2018 and 2019. Gokkus et al. (1996) reported that the difference in yield potentials between cultivars may be due to the difference in their adaptability as well as the characteristics, and may also be due to the difference in climatic values during the year. Bakoğlu (2009) determined this crops grain yield within 616-1099 kg ha^{-1}, Mart et al. (2017) reported that it varied between 1143-2645 kg ha^{-1}, and it seems to agree with our findings from the study.

Microbial, organic and inorganic fertilizer applications related to grain yield have been the subject of studies on chickpea plant; Kaya et al. (2008), in their study on the effect of organic (slempe) and commercial fertilizer on chickpea, determined that the lowest grain yield was obtained from control plots without fertilizer (1088 kg ha^{-1}), which the results of commercial fertilizer and organic fertilizer (slempe) applications were close to each other. They reported that more grain was obtained from fertilizer applications. Elkoca et al. (2008), in their study on microbial and chemical fertilizer applications on chickpea plants, reported that there was a difference between the applications, thus the lowest grain yield was in the control plots, the highest grain yield was obtained from the NP application, and the difference between microbial fertilizers was not statistically significant. Amin and Moghadasi (2015) reported that they obtained the lowest grain yield from the control plots of the chickpea plant while high grain yield was achieved from chickpea plants under nitrogen fertilizer and vermicompost applications, although the difference was insignificant. Our findings are consistent with the findings of the aforementioned researchers. Many researchers have reported that the addition of biofertilizers to chemical and organic fertilizers significantly increases grain yield (Narayana et al. 2009, Rajeshwar, Khan 2010).

Biological yield

Table 12 shows data on the biological yield of the varieties under the application of different fertilizers during the two years of the study. In 2018, the Arda variety had higher biological yield (7478 kg ha^{-1}) than the Azkan variety (6757 kg ha^{-1}). In the same year, the biological yield ranged within

Table 12

Average values of the biological yield from chickpea plants after the application of microbial, organic fertilizers and inorganic fertilizers

Applications	2018 years			2019 years			Variety x applications		Mean
	Arda	Azkan	mean	Arda	Azkan	mean	Arda	Azkan	
Control	7043	6242	6642*d*	6220	6108	6164*c*	6631	6175	6403*E*
DAP/2	7352	6396	6874*cd*	6737	6274	6505*b*	7044	6335	6690*D*
DAP	7560	6712	7136*bc*	6890	6438	6664*ab*	7225	6575	6900*C*
Chicken manure	7831	6989	7410*a*	7173	6620	6897*a*	7502	6805	7153*A*
Vermicompost	7490	6909	7199*ab*	7062	6436	6749*ab*	7276	6672	6974*AC*
Farm manure	7571	7018	7295*ab*	7226	6676	6951*a*	7398	6847	7123*AB*
TV126C	7522	6883	7203*ab*	7093	6388	6740*ab*	7308	6636	6972*AC*
TV119E	7488	6868	7178*ab*	7009	6333	6671*ab*	7249	6601	6925*BC*
TV53D	7442	6799	7121*bc*	7125	6325	6725*ab*	7284	6562	6923*BC*
Mean	7478*A*	6757*B*	7118*A*	6948*A*	6400*B*	6674*B*	7213*A*	6579*B*	
CV (%)	3.19			3.99			3.58		

6642-7410 kg ha^{-1}, and the lowest biological yield was obtained in the control plots, while the highest biological yield was obtained from the chicken manure application (7410 kg ha^{-1}). In 2019, lower biological yield was obtained from the Azkan variety (6400 kg ha^{-1}) than from the Arda variety (6948 kg ha^{-1}). In the context of applications, the biological yield was between 6164-6897 kg ha^{-1}, and the lowest one was obtained from the control plots, while the highest biological yield was obtained after the application of chicken manure.

When the combined averages of both years were examined in the study, higher biological yields were obtained from Arda variety (7213 kg ha^{-1}) compared to the Azkan variety (6578 kg ha^{-1}). The effect of different applications on grain yield is significant, as the lowest biological yield was obtained from the control plots at 6403 kg ha^{-1}, followed by DAP/2 application, and the highest biological yield was obtained from chicken manure application at 7153 kg ha^{-1}.

Differences between years in terms of biological yield are thought to have resulted from the climate data of 2018 and 2019, and the biological yield also changed depending on the plant height. Amin and Moghadasi (2015) examined the effects of vermicompost and nitrogen fertilizer applications on biological yield from chickpea plants. They reported that the lowest values were obtained from the control plots and that high values were obtained in the applications where nitrogen fertilizer and vermicompost were given, but the differences were insignificant. Sadeghipour (2017), in a study involving the application of vermicompost and chemical fertilizers, reported that the lowest biological efficiency was obtained from the control plots, followed by the NPK application, while the highest biological efficiency was obtained from the vermicompost application, and the difference between the applications where 75% vermicompost + 25% NPK was applied together was insignificant. Our findings are partially similar to the findings of these researchers. It should be emphasized that organic-sourced fertilizers have a significant and positive effect on the availability of nutrients in the soil, and positively affect plant growth as well as the physical, chemical and biological properties of the soil.

Harvest index

In 2019, the harvest index values of the Arda variety were higher than those of the Azkan variety. In the second year, the harvest index values changed between 28.3-33.0% depending on the applications, while the lowest value was obtained in the control plots, and the highest harvest index was obtained in the chicken manure application. When the combined average values of both years were examined, the Arda variety had a 30.3% harvest index and the Azkan variety achieved a 30.4% harvest index value (Table 13).

The effect of different applications on the harvest index was as follows: the control plot had the lowest harvest index (28.3%), followed by the DAP/2 application, while the highest harvest index was obtained from the chicken manure application (33.0%), followed by farm manure and vermicompost applications, which were close to each other. The difference between the years in terms of the harvest index is due to the climatic characteristics

Table 13

Average values of the harvest index of chickpea plants after the application of microbial, organic fertilizer and inorganic fertilizers

Applications	2018 years			2019 years			Variety x applications		Mean
	Arda	Azkan	mean	Arda	Azkan	mean	Arda	Azkan	
Control	28.0	28.3	28.2*f*	28.7	28.0	28.3 *d*	28.3	28.2	28.3*E*
DAP/2	30.3	29.7	30.0*e*	28.7	29.0	28.8*cd*	29.5	29.3	29.4*D*
DAP	31.7	30.3	31.0*bd*	29.7	30.3	30.3*bc*	30.7	30.3	30.5*BC*
Chicken manure	33.0	33.0	33.0*a*	32.7	33.3	33.0*a*	32.8	33.2	33.0*A*
Vermicompost	31.3	31.7	31.5*b*	30.3	30.7	30.5*b*	30.8	31.2	31.0*B*
Farm manure	31.3	31.3	31.3*bc*	29.7	30.3	30.0*bc*	30.5	30.8	30.7*BC*
TV126C	30.7	31.3	31.3*bd*	29.7	30.3	30.0*bc*	30.2	30.8	30.5*BC*
TV119E	31.0	30.0	30.5*ce*	28.9	30.0	29.4*bd*	30.0	30.0	30.0*CD*
TV53D	30.3	30.3	30.3*de*	29.4	30.0	29.7*bc*	29.9	30.2	30.0*CD*
Mean	30.9	30.7	30.8*A*	29.7	30.2	30.0 *B*	30.3	30.4	
CV (%)	2.74			3.60			3.18		

of the years. Doğan et al. (2015) reported that the differences between chickpea varieties are important in terms of the harvest index. Researchers suggested that these differences may depend on the variety used and the climatic characteristics of the growing period (McKenzie, Hill 1995, Deshmukh et al. 2004).

Studies on other plants and their response to microbial, organic and inorganic fertilizer applications have been performed. Yeşirbaş (2015) in a study on lentils reported that the highest harvest index was obtained after chicken manure application (37.4%), the lowest average value was obtained from control plots (32.8%), and the effect of chicken manure was followed that produced by sheep manure and DAP. Our findings are consistent with the findings of other researchers. Toğay et al. (2005) used different nitrogen doses and four different nitrogen forms in cultivation of lentils, and obtained the highest harvest index after the application of organic nitrogen, while Saket et al. (2014), who also studied lentils, reported that the highest harvest index of these plants was obtained after the farm manure application, followed by vermicompost and chicken manure applications.

Protein ratio

When the combined mean values were examined, the Arda variety had 23.2% protein, and the Azkan variety had 21.1% protein. Although the effect of different applications on the protein ratio is significant, the lowest protein ratio was obtained from the control plots, while the highest protein ratio was achieved after the chicken manure application with 23.7%, and the results of the all applications were close to each other (Table 14).

Table 14

Average values of protein ratio in chickpea plants after the application of microbial, organic fertilizer and inorganic fertilizers

Applications	2018 years			2019 years			Variety x applications		Mean
	Arda	Azkan	mean	Arda	Azkan	mean	Arda	Azkan	
Control	22.0	18.8	20.4*e*	22.0*c*	18.7*g*	20.4*d*	22.0*d*	18.8*i*	20.4*G*
DAP/2	22.8	20.4	21.6*d*	23.0*b*	20.5*f*	21.7*c*	22.9*c*	20.5*h*	21.7*F*
DAP	23.4	21.5	22.4*b*	23.5*ab*	21.4*ce*	22.5*b*	23.5*b*	21.5*ef*	22.5*BC*
Chicken manure	24.6	23.0	23.8*a*	24.2*a*	22.9*b*	23.6*a*	24.4*a*	23.0*c*	23.7*A*
Vermicompost	23.0	21.4	22.2*bc*	23.2*b*	21.1*df*	22.1*bc*	23.1*bc*	21.3*ef*	22.2*CE*
Farm manure	23.1	20.7	21.9*cd*	23.4*b*	20.8*ef*	22.1*bc*	23.2*bc*	20.7*gh*	22.0*E*
TV126C	23.1	21.7	22.4*b*	23.0*b*	21.4*ce*	22.2*bc*	23.1*bc*	21.6*f*	22.3*BD*
TV119E	23.0	21.2	22.1*bc*	23.1*b*	21.0*ef*	22.0*bc*	23.1*bc*	21.1*fg*	22.1*DE*
TV53D	23.6	21.2	22.4*b*	23.5*ab*	21.7*cd*	22.6*b*	23.5*b*	21.5*ef*	22.5*B*
Mean	23.2*A*	21.1*B*	22.1	23.2*A*	21.1*B*	22.1	23.2*A*	21.1*B*	
CV (%)	1.32			2.00			1.65		

Mart *et al.* (2017) indicated that the protein content varied between 17.5-20.7% among chickpea cultivars. They reported that differences depending on climatic properties, which significantly affected the protein ratio of chickpea grain. Elkoca *et al.* (2008) reported that the lowest protein ratio was obtained in the control plots (23.9%), while the highest protein ratio was obtained from the application of rhizobium + nitrogen-fixing microbial fertilizer (26.2%), followed by N and NP applications (25.4%). Mohammedi et al. (2010) reported that the lowest values were found in the control plots (21.15%), and the effect of bacterial applications was lower than in other applications.

Grain phosphorus content

The effect of the combined analyses on the grain phosphorus content in the overall average of different applications was significant. While the lowest grain phosphorus ratio was obtained from the control plots; DAP/2, chicken manure, (NP)TV 53D, (N)TV 126C, DAP and vermicompost applications were followed, with the highest value obtained in farmyard manure application (Table 15).

The cultivars differed in terms of the phosphorus content in grain. Doğan (2015) stated that it varies between 237.8-324.3 mg kg^{-1}. Our findings concide with the findings obtained from different studies. Wang and Daun (2004) found the amount of phosphorus in grain varying in the range of 240-830 mg kg^{-1} in Australian ram-type chickpeas and 294.1-828.8 mg kg^{-1} in Canadian ram-type chickpeas. Haq et al. (2007) reported that the grain phosphorus content varied between 246-259 mg kg^{-1}. It is seen that the

Table 15

Average values of phosphorus ratio in chickpea plants after the application of microbial, organic fertilizer and inorganic fertilizers

Applications	2018 years			2019 years			Variety x applications		Mean
	Arda	Azkan	mean	Arda	Azkan	mean	Arda	Azkan	
Control	281.4	291.8	286.6*h*	275.0*j*	289.7*i*	282.4*f*	278.2*k*	290.8*j*	284.5*H*
DAP/2	292.2	303.2	297.7*g*	290.0*i*	303.7*e*	296.9*e*	291.1*j*	303.5*f*	297.3*G*
DAP	301.0	312.9	307.0*cd*	298.4*fh*	311.6*d*	305.0*cd*	299.7*gh*	312.3*de*	306.0*D*
Chicken manure	296.3	303.7	300.0*fg*	299.3*eg*	304.2*e*	301.8*d*	297.8 *h*	304.0*f*	300.9*F*
Vermicompost	310.3	318.3	314.3*b*	311.3*d*	317.4*c*	314.4*b*	310.8*e*	317.9*c*	314.3*B*
Farm manure	321.2	331.2	326.2*a*	322.6*b*	330.2*a*	326.4*a*	321.9*b*	330.7*a*	326.3*A*
TV126C	296.5	310.7	303.6*de*	296.8*gh*	312.8*cd*	304.8*d*	296.7*hi*	311.7*de*	304.2*DE*
TV119E	301.3	316.0	308.7*c*	303.5*ef*	314.2*cd*	308.9*c*	302.4*fg*	315.1*ce*	308.8*C*
TV53D	293.6	310.1	301.9*ef*	293.2*hi*	310.4*d*	301.8*d*	293.4*ij*	310.3*e*	301.8*EF*
Mean	299.3*B*	310.9*A*	305.1	298.9*B*	310.5*A*	304.7	299.1*B*	310.7*A*	
CV (%)	0.99			1.01			1.00		

results achieved in the aforementioned studies are close to ours. Mohammedi et al. (2010), and Saket et al. (2014) reported that the lowest value of the phosphorus content in grain was obtained from non-treated plots, followed by those treated with compost fertilizer, whereas the highest grain phosphorus content was obtained from the plots fertilized with farm manure and 100% NPK (20/40/20). It was determined that the phosphorus content values obtained from the TV119E phosphorus solvent bacteria application in the microbial fertilizer used were higher than from the TV126C and TV 53D applications. Phosphate solubilizng bacteria applied in the research contributed positively to the grain phosphorus content. In their studies, they reported that inoculation with nitrogen-fixing and especially phosphorus-solubilizing bacteria increases the phosphorus content of the plant (Afzal, Asghari 2008).

Grain potassium content

When the combined average values were examined, Azkan variety had 719.8 mg kg^{-1} grain potassium content and Arda variety had 698.7 mg kg^{-1} grain potassium content. The effect of different applications on grain potassium content was significant. While the lowest grain potassium content was obtained from the control plots where no application was made, the highest potassium content was obtained in the farm manure application (Table 16).

The varieties differed in annual averages in terms of potassium content in the grain. Doğan (2015) reported that the average values of potassium content in the grain of chickpea variety varied between 556.8-727.9 mg kg^{-1}. Our findings are aggreement with the data from earlier studies.

Table 16

Average values of potassium content in grain of chickpea plants after the application of microbial, organic fertilizer and inorganic fertilizers

Applications	2018 years			2019 years			Variety x applications		Mean
	Arda	Azkan	mean	Arda	Azkan	mean	Arda	Azkan	
Control	673.1	688.4	681.0	699.7	681.0	699.7	680.8*bc*	690.4*ac*	685.6
DAP/2	693.5	798.3	697.3	704.3	697.3	704.3	745.9 *a*	700.8*ac*	723.4
DAP	703.4	713.4	705.7	711.7	705.7	711.7	708.4*ac*	708.7*ac*	708.6
Chicken manure	702.3	720.1	710.5	716.7	710.5	716.7	711.2*ac*	713.6*ac*	712.4
Vermicompost	719.6	731.7	723.1	727.2	723.1	727.2	725.7*ac*	725.2*ac*	725.4
Farm manure	730.1	739.7	601.6	740.4	601.6	740.4	734.9*ab*	671.0*c*	702.9
TV126C	702.3	710.7	707.5	712.1	707.5	712.1	706.5 *ac*	709.8*ac*	708.2
TV119E	702.4	710.0	708.5	713.7	708.5	713.7	706.2 *ac*	711.1*ac*	708.6
TV53D	701.7	707.9	712.5	710.8	712.5	710.8	704.8 *ac*	711.7*ac*	708.2
Mean	703.2	724.5	713.8	694.2	715.2	704.7	698.7*B*	719.8*A*	
CV (%)	5.74			7.97			6.90		

Mohammedi et al. (2010) reported that the lowest potassium content was in grain from plants treated with compost application, followed by farm manure, farm + compost fertilizers, and farm + compost + TSP (triple super phosphate) application. On the other hand, Saket et al. (2014) examined the effect of organic and inorganic fertilization on yield parameters in lentils, and found that the lowest potassium content was obtained in the control plots, followed by compost fertilizer, while the highest grain potassium content was obtained from farm manure and 100% NPK applications (20).

CONCLUSION

In this research, apart from organic and inorganic fertilizers, which are from different fertilizer sources, the use of chemical fertilizers is becoming more and more common, causing significant damage to the environment, especially to the soil. Considering the use and cost of chemical fertilizers, it has a very serious negative impact on the country's economy. Pollution of the drinking water due to the use of chemical fertilizers has a permanent and destructive effect on the population living in the ecosystem. The elimination of these adverse consequence takes a very long time and sometimes is impossible. It is very important to promote the use of environmentally friendly organic resources for sustainable agriculture and the environment. In this context, it is essential to extend the use of organic fertilizer resources and to protect living organisms in the ecosystem, especially humans, and the soil, which is a living source. In this context, organic farming practices that increase food safety, especially in our region and ultimately in our country, should be developed within the scope of agricultural production. Therefore, in this study, the effects of fertilizer applications differ in terms of the properties examined, all applications contributed to obtaining better results than the control plots, and chicken manure used as organic fertilizer affects yield and yield parameters positively. Microbial fertilizer increases the yield at least as much as DAP fertilizer and vermicompost. It has been determined that farm manure after chicken manure can be recommended for cultivation of chickpea.

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