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The Effects of *Mesorhizobium ciceri* Inoculation and Different Doses of Vermicompost Treatments on the Yield Components and Yield of Chickpea (*Cicer arietinum* L.) under Semi-arid Mediterranean Highland Condition of Turkey

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ABSTRACT

Background: This study was conducted in 2016-2017 to determine the effects of *Mesorhizobium ciceri* inoculation and different doses of vermicompost applications on the yield components and yield of chickpea under semi-arid Mediterranean highland condition of Turkey.

Methods: *Mesorhizobium ciceri* inoculant were applied to seeds (at 10^8 cfu bacteria per seed dose) as microbial fertilizer in the experiments. Vermicompost doses were 0, 1000, 2000 and 3000 kg ha^{-1}. The trials were set up with three replications according to the randomized complete blocks design.

Conclusion: Plant height, first pod height, pod number per plant, number of seeds per plant, 100 grain weight and grain yield were determined as 56.1-61.9 cm, 29.4-34.9 cm, 31.4-46.3 pods plant^{-1}, 32.9-44.0 seed plant^{-1}, 30.4-37.4 g and 1463-2072 kg ha^{-1}, respectively. Co-application of 1000 kg ha^{-1} vermicompost with *Mesorhizobium ciceri* inoculation produced the highest values for all examined parameters for both years. Further applications of vermicompost reduced yield and related components. Control parcels and excess vermicompost applications (2000 and 3000 kg ha^{-1}) produced lowest values. *Mesorhizobium ciceri* inoculation produced medium values between Co-application of 1000 kg ha^{-1} vermicompost with *Mesorhizobium ciceri* and control and excess vermicompost applied conditions. In conclusion, use of *Mesorhizobium ciceri* + 1000 kg ha^{-1} vermicompost was recommended in chickpea cultivation for maximum yield in the ecological conditions of Siirt province of Turkey or in similar ecologies.

Key words: Biofertilizer, *Cicer arietinum* L., *Mesorhizobium*, Vermicompost, Yield.

INTRODUCTION

Approximately 11.000 years ago groups of hunters abandoned their mobile lifestyles for growing crops. This shift accelerated the rise of civilisations in the human history (Zohary *et al.,* 2012). Eight crops were founded in Neolithic agriculture in the Near East: 1) Emmer wheat (*Triticum turgidum* subsp. *dicoccum*), 2) Einkorn wheat (*T. monococcum*), 3) Pea (*Pisum sativum*), 4) Lentil (*Lens culinaris*) 5) Chickpea (*Cicer arietinum*), 6) Bitter vetch (*Vicia ervilia*), 7) Flax (*Linum usitatissimum*) 8) Barley (*Hordeum vulgare*) (Zohary, 1999).

Chickpea (*Cicer arietinum* L.) is a very important cool-season crop which provides nutritious food for the expanding global population and it will probably become more important with climate change (Torkaman *et al.,* 2018; Merga and Haji, 2019). Its production is less demanding to external inputs compared to cereals. Chickpea is an important species in the cropping patterns supplying cheap protein diets especially for low income people (Baloch and Zubair, 2010). Chickpea is the most produced pulse crop in Turkey. Acreage, yield and amount of harvested grain values for Turkey in 2020 were 511 thousand ha, 0.12 t ha^{-1} and 630 thousand tons, respectively (TSI, 2021). In the world, it ranks second after dry beans (FAO, 2021). It can be grown as a summer and winter crop in Turkey (Karaağaç *et al.,* 2019).

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Biofertilizers have been used to improve availability of plant nutrients in agriculture (Han and Lee, 2006; Anjali *et al.,* 2021). Many rhizospheric fungi and bacteria known as plant growth promoting microorganisms have ability to infect plant roots to provide benefits like drought and salinity tolerance to their hosts (Groppa *et al.,* 2012). The chickpea plant increases the nitrogen content of the soil besides gaining the nitrogen it needs by fixing free N_2 of air (Sevilmis and Sevilmis, 2019). The amount of nitrogen fixed varies depending on the number of bacteria and their nitrogen-fixing capacity (Erdil *et al.,* 2018). Each *Rhizobium* spp. bacterial species has a specific host plant (Cevheri and Küçük, 2020). *Mesorhizobium ciceri* is the symbiotic partner species for chickpeas.

Organic matter has a significant role in increasing the microbial activity in the soil. As the organic matter content increases, the permeability of the soils increases and becomes looser. Soils of Turkey are generally low in organic matter content due to decomposition under high temperatures. Vermicomposting is a process of converting organic materials into humus like substance by earthworms (Lim *et al.,* 2015). This non-thermophilic and bio-oxidative process helps to decompose biological organic wastes by associated microbes (Pathma and Sakthivel, 2012). Vermicomposting is a low-technology and environment-friendly process (Lazcano and Dominguez, 2011). Resultant vermicompost is a finely structured, peat like material with high porosity, good aeration, drainage, water holding capacity, buffering capacity which enhance soil beneficial microbe biodiversity (Pathma and Sakthivel, 2012). Vermicomposts may improve physical, chemical and biological structure of soil with their better nutrient profile than traditional composts. Chemically improved properties are pH, electrical conductivity and organic matter content (Lim *et al.,* 2015). It also enhances plant growth by production of plant growth-regulating hormones and enzymes (Pathma and Sakthivel, 2012). This agricultural and horticultural organic fertilizer increasingly seen as a good alternative to inorganic fertilizers (Lazcano and Dominguez, 2011). This study was aimed to determine the effects of *Mesorhizobium ciceri* bacteria and worm manure on the yield characteristics and yield of chickpea without applying any chemical fertilizers under soil conditions of high rate of natural clay-chelated phosphorous in soil.

MATERIALS AND METHODS

The research was carried out in the experimental area of Siirt University during 2016 and 2017 spring growth seasons. Siirt province is at the altitude of 902 m, located in the Southeastern Anatolia Region on 41°57′ east longitude and 37°55′ north latitude. Trial area is in fertile crescent and 180 km away to Karacadag Mountains (Diyarbakir) where Einkorn wheat (*Aegilops monococcum* L.) was first cultivated in history approximately 10 thousand years ago.

Azkan variety chickpea seed was used in the experiment. Azkan variety has upright growth habit, medium level branching, early maturing and drought and cold tolerant (Anonymous, 2019).

Mesorhizobium ciceri bacteria were used for inoculation and vermicompost (prepared from 70% cow manure and 30% vegetable waste) were used as organic fertilizer in the study. Vermicompost was excrete of red California worms (*Eisenia foetida*) (pH 6.5-8.5; organic matter content 35%, total N content 1.2%; Ekosol brand; Turkey). *Mesorhizobium ciceri* bacteria was used as microbial inoculant which was obtained in a peat culture medium from the "Soil Fertilizer and Water Resources Central Research Institute" (Ankara, Turkey). Dose for *Mesorhizobium ciceri* inoculant applied to seeds was 10^8 cfu per seed. Soil of the trial field was clayey-loam, nearly flat, poor in organic matter (1.02%), salt-free (0.40 dS m^{-1}), calcareous ($CaCO_3$, 0.48%), slightly alkaline (pH: 7.6), rich in potassium content (660 kg ha^{-1}) and rich in phosphorus content (33.3 kg ha^{-1}).

Terrestrial climate exist in Siirt with hot and dry summers and with common precipitation between March and June. Agroclimatic characteristics of Siirt province are suitable for chickpea cultivation. Meteorological data of the trial area is given in Table 1.

Average temperature was similar to the long-term average in the first year, while it was 1.4°C lower in the second year. Annual rainfall in 2016 and 2017 remained below the long term average. Relative humidity values were approximated to the long term averages (Table 1).

The trials were set up on three replications according to the randomized complete blocks design. Sowings were conducted in the first week of March, on four rows in each plot, on 5 m long rows, with 30 cm inter-row spacing and at sawing density of 60 seeds/m^2. Before planting, total 0, 1000, 2000, and 3000 kg ha^{-1} doses of vermicompost were spread on the parcels before harrowing.

Plant seeds were soaked in water containing sugar at 4% concentration, hold 10 seconds and then put into bacteria carrier peat media for inoculation with *Mesorhizobium ciceri*

Table 1: Metrological data of the research area**.

Months	Monthly average temperature (°C)			Monthly total precipitation (mm)			Monthly average relative humidity (%)		
	2016	2017	Long term average*	2016	2017	Long term average*	2016	2017	Long term average*
February	8.1	2.7	4.2	63.8	45.6	975	68.3	64.9	66.8
March	10.1	9.6	8.3	136.6	118.8	111.1	62.3	63.9	61.6
April	16.6	14.0	13.7	66.8	128.1	104.7	4.5	59.5	550
May	19.9	19.5	19.3	64.7	74.8	62.0	48.9	51.7	49.7
June	26.5	26.9	26.0	20.6	0.0	8.7	32.7	29.5	31.5
July	31.4	32.3	30.6	2.4	0.0	1.6	24.5	19.0	23.5
Aver./Total	17.2	15.6	17.0	354.9	367.3	385.6	47.4	48.1	48.0

*Long term average (1963-2017), **Turkish State Meteorological Service, Siirt Province Official Records.

bacteria with dose of 1 kg peat culture/50 kg seeds (at 10^8 cfu bacteria per seed). Seeds were mixed in peat-inoculant media approximately 1 minute. These procedures were conducted in a shadow condition in the morning before 3 hours of seed sowing.

Rainfed chickpea cultivation technique was applied. No irrigating was applied. Weed control was done mechanically. For observation and harvesting, one row from the edges of the plots and 0.5 m from the both ends of the plots cut out. 10 plants selected from the remaining plants for observations, except grain yield parameter. For plant height, distance between shoot to soil levels were measured. For first pod height, distance between first pod to soil levels were measured. Parcel harvest was conducted for yield determinations. Plant height, first pod height, number of pods per plant, number of seeds per plant, 100-grain weight, and grain yield were recorded.

Pesticides against anthracnose was applied at three times in 2017 and one time in 2016. The plants were harvested in the first week of July when the pods are dried and the grains were hardened. Harvesting and threshing operations were done manually. The data were subjected to variance analysis and differences between the applications were determined by the $\text{Tukey}_{(0.05)}$ test *via* JMP (version 5.0.1) software program.

RESULTS AND DISCUSSION

The effects of years and applications on plant height, first pod height and the number of seeds per plant were statistically significant. The effects of years, applications, and year × application interaction on the number of pods per plant, 100-grain weight, and grain yield were statistically significant (Table 2 and 3).

Plant heights were between 56.1-61.9 cm, first pod heights were between 29.4-34.9 cm, pod number per plant values were between 31.4-46.3, number of seeds per plant values were between 32.9-44.0, 100-grain weight values were between 30.4-37.4 g and grain yields were between 1463-2072 kg ha^{-1} (Table 2 and 3). Values for all parameters were lower in 2017 than in 2016. In 2017, anthracnose disease negatively affected the vegetative and generative growth of plants. Pesticides were used against anthracnose disease once in 2016, and three times in 2017. Depending on this disease, plant heights were shorter, and grain yields were lower in 2017 compared to 2016. The highest values for all parameters were obtained from *Mesorhizobium ciceri* + 1000 kg ha^{-1} vermicompost application. This was followed by applications of sole 1000 kg ha^{-1} vermicompost and sole 2000 kg ha^{-1} vermicompost.

The lowest values were detected by *Mesorhizobium ciceri* + 3000 kg ha^{-1} vermicompost application. Siirt province is located in the gene center of the chickpea. South Eastern Anatolia is in gene origin zone of chickpeas and soils naturally contain *Mesorhizobium ciceri* bacteria (Erdoğan, 1997). However, the number and nitrogen-fixing capacity of these bacteria are unknown. The organic matter content of Siirt province soils is low. However, if the nitrogen content in the soil increases to excess levels, the microbial activities of *Mesorhizobium ciceri* bacteria may decrease (Uyanık *et al.,* 2011). *Mesorhizobium ciceri* bacteria inoculation and vermicompost application exceeding 1000 kg ha^{-1} resulted a decrease in the growth parameters. When the effect of year × application interaction on the number of pods per plant, 100-grain weight, and grain yield was examined, the highest values were obtained from *Mesorhizobium ciceri* + 1000 kg ha^{-1} vermicompost application in 2016. The lowest values of all parameters were detected in *Mesorhizobium ciceri* + 3000 kg ha^{-1} vermicompost application in 2017. *Mesorhizobium ciceri* inoculation produced medium values between co-application of 1000 kg ha^{-1} vermicompost with

Table 2: The effects of the applications on the plant height, the first pod height and the number of pods per plant values of the chickpea.

Treatments	Plant height (cm)			First pod height (cm)			Number of pods per plant (pods plant^{-1})		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Control	58.3	56.7	57.5 E	32.6	29.9	31.3 CD	38.1 e	32.0 jk	35.1 E
1000 kg ha^{-1} VC	60.9	59.6	60.3 B	34.0	31.8	32.9 B	43.1 b	34.4 g-i	38.8 B
2000 kg ha^{-1} VC	60.9	59.1	60.0 BC	33.8	31.5	32.7 B	41.4 c	33.7 hi	37.6 C
3000 kg ha^{-1} VC	60.1	58.7	59.4 C	32.6	31.1	31.9 C	39.3 de	33.2 ij	36.3 D
Mesorhizobium ciceri	59.1	57.7	58.4 D	32.5	31.1	31.8 C	39.8 d	33.2 ij	36.5 D
M.c. + 1000 kg ha^{-1} VC	61.9	60.7	61.3 A	34.9	32.7	33.8 A	46.3 a	36.1 f	41.2 A
M.c. + 2000 kg ha^{-1} VC	58.0	56.7	57.3 E	31.6	29.8	30.7 DE	35.2 fg	31.9 jk	33.5 F
M.c. + 3000 kg ha^{-1} VC	58.2	56.1	57.2 E	31.2	29.4	30.3 E	34.6 gh	31.4 k	33.0 F
Mean	59.7 A	58.2 B		32.9 A	30.9 B		39.7 A	33.2 B	
$\text{Tukey}_{(0.05)}$									
Year		0.186			0.295			0.331	
Application		0.778			0.732			0.837	
Application × year		n.s.			n.s.			1.358	

*VC: Vermicompost; *M.c.*: *Mesorhizobium ciceri*; Different letters in the rows indicate significant differences according to Tukey's test (P≤0.05); n.s.: non significant

Table 3: The effects of the applications on the number of seeds per plant, 100-grain weight, and the grain yield of the chickpea.

Treatments	Number of seeds per plant (seed plant^{-1})			100-grain weight (g)			Grain yield (kg ha^{-1})		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Control	40.5	33.6	37.1 DE	34.3 e	32.1 gh	33.2 D	1646 f-h	1561 i	1604 E
1000 kg ha^{-1} VC	42.3	35.4	38.9 B	36.5 ab	33.8 ef	35.2 B	1999 b	1762 d	1881 B
2000 kg ha^{-1} VC	41.6	34.7	38.2 BC	35.8 bc	32.3 gh	34.1 C	1869 c	1718 de	1794 C
3000 kg ha^{-1} VC	41.3	34.4	37.9 CD	35.4 cd	31.9 h	33.7 CD	1691 e-g	1623 hi	1657 D
Mesorhizobium ciceri	41.5	34.6	38.1 BC	35.5 bc	33.0 fg	34.3 C	1632 gh	1701 d-f	1667 D
M.c. + 1000 kg ha^{-1} VC	44.0	37.1	40.6 A	37.4 a	34.5 de	35.9 A	2072 a	1832 c	1952 A
M.c. + 2000 kg ha^{-1} VC	39.9	33.0	36.5 E	33.9 ef	30.5 i	32.2 E	1610 hi	1587 hi	1599 E
M.c. + 3000 kg ha^{-1} VC	39.8	32.9	36.4 E	33.7 ef	30.4 i	32.1 E	1595 hi	1463 j	1529 F
Mean	41.4 A	34.5 B		35.3 A	32.3 B		1764 A	1656 B	
Tukey$_{(0.05)}$									
Year		0.361			0.166			16.341	
Application		0.856			0.599			24.772	
Application × Year		n.s.			0.972			35.005	

*VC: Vermicompost; *M.c.*: *Mesorhizobium ciceri*; different letters in the rows indicate significant differences according to Tukey's test (P≤0.05); n.s.: non significant.

Mesorhizobium ciceri and control and excess vermicompost applied conditions.

Uçar *et al.* (2020) reported that vermicompost application increased chickpea plant height, first pod height, pod number per plant, number of grain per plant, 100-grain weight and grain yield in their study. Kumar *et al.* (2014) reported that vermicompost applications increased plant height, pod number per plant, 100-grain weight, and grain yield compared to control. Gopalakrishnan *et al.* (2014) and Amiri *et al.* (2016) determined that vermicompost applications increased the plant height of the chickpea plants and the number of pods. Uçar and Erman (2020), Soysal and Erman (2020) determined that *Mesorhizobium ciceri* bacteria inoculation was increased the plant size of chickpeas. Pashaki *et al.* (2016) reported that microbial fertilizer and vermicompost application increased the number of pods, the number of seeds, and the grain yield. Similar results were also determined by Singh *et al.* (2012) and Bhattachariya and Chandra (2013) for the chickpeas at different location.

CONCLUSION

Significant effects were determined by vermicompost application and *Mesorhizobium ciceri* bacteria inoculation on grain yield and yield components. The highest values for all characteristics were obtained by *Mesorhizobium ciceri* + 1000 kg ha^{-1} vermicompost application. The effect of *Mesorhizobium ciceri* + 2000 kg ha^{-1} vermicompost and *Mesorhizobium ciceri* + 3000 kg ha^{-1} vermicompost applications on the parameters were lower than the control. As a result of the study, *Mesorhizobium ciceri* inoculation + 1000 kg ha^{-1} vermicompost application was recommended in the chickpea cultivation in the ecological conditions of Siirt province in Turkey and in similar ecologies.

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