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Effects of Microbial Fertilizer and Vermicompost Applications on the Yield and Yield Related Parameters of Broad Bean (*Vicia faba* L.) under Eastern Mediterranean Highland Agroclimatic Conditions

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ABSTRACT

Background: This study was conducted to determine the effects of microbial fertilizer and vermicompost applications on the yield and yield related parameters of broad beans (*Vicia faba* L.) under zero chemical fertilizer applied conditions. Trial area was a highland remote to sea under Mediterranean climate in South Eastern Anatolia of Turkey. It is located in fertile crescent and 180 km away to Karacadag Mountains (Diyarbakir) where Einkorn wheat (*Aegilops monococcum* L.) was first cultivated in history approximately ten thousand years ago. The broad bean was also among the founder crops of the Near East including the trial location.

Methods: *Rhizobium leguminosarum* inoculant were used as microbial fertilizer in the experiments. Applied vermicompost doses were 0, 400, 800 and 1200 kg ha^{-1}. The trials was conducted for two years and replicated thrice in a randomized block deign.

Conclusion: Application of vermicompost was found significantly effective on the plant height, first pod height, number of pods per plant, number of seeds per pod, 100 grain weight and grain yield. Aapplication of 800 kg ha^{-1} and 120 kg ha^{-1} vermicompost along with *Rhizobium leguminosarum* inoculation was found superior for grain yield.

Key words: Biofertilizer, *Rhizobium, Vicia faba* L., Vermicompost, Yield.

INTRODUCTION

Nitrogen (N) is a main yield limiting nutrient in crop production around the world (Fageria, 2014). Agricultural activity has large influence on the global N cycle by introducing large amounts of reactive nitrogen (fertilizers) into ecosystems. A big part of this nitrogen leaks into the environment with important negative effects on ecosystem and global warming. Natural ecosystems use multiple pathways in reaction to this flow. Agricultural systems cycle it primarily through the nitrification process which allows reactive N leak into the environment (Subbarao *et al.*, 2012).

The N use efficiency of agricultural plants is poor. About 50% of the N fertilizer applied to soils is not absorbed by plants and lost as ammonia (NH_3), nitrate (NO_3^-) and nitrous oxide (N_2O). These losses are driven by volatilization of NH_3 and by nitrification and denitrification reactions catalyzed by soil microorganisms (bacteria) (Coskun *et al.,* 2017).

Deficit of access to mineral N limits plant growth, and so symbiotic relations between plants and a variety of nitrogen-fixing organisms have evolved. Plant associations with nitrogen-fixing organisms are responsible for reducing 120 million tonnes of atmospheric N to ammonia every year (Freiberg *et al.,* 1997). The use of biofertilisers such as *rhizobia* and arbuscular mycorrhizal fungi in legume crops is a sustainable technology as an alternative source of nitrogen (Pereira *et al*., 2019). *Rhizobium leguminosarum* race infect *Vicia faba* plants to nodulate to fix atmospheric nitrogen (Ventorino *et al.,* 2007).

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Vermicompost is a finely divided, peat like material with high porosity, good aeration, drainage and water holding capacity (Pathma and Sakthivel, 2012). Vermicomposting is a process of converting organic materials into humus like-substance by earthworms (Lim *et al.,* 2015). Vermicompost contains N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B and humic acids. It promotes pests and diseases tolerance of crops by the synthesis of anthocyanins and flavonoids (Theunissen *et al.,* 2010). It also enhances plant growth by production of hormones and enzymes (Pathma and Sakthivel, 2012). This organic fertilizer increasingly becoming a good alternative to inorganic fertilizers (Lazcano and Domínguez, 2011). However, high concentrations of soluble salts that may be available in vermicomposts may reduce growth by

application of vermicomposts at high concentrations. So, application of moderate amounts of vermicompost is better to escape this risk (Lim *et al.,* 2015). This study was aimed to determine the effects of *Rhizobium leguminosarum* bacteria and vermicompost on the yield and yield related characteristics of broad bean.

MATERIALS AND METHODS

The study was carried out in the fields of Siirt University, in Turkey, during 2017 and 2018 growing seasons. Broad bean (*Vicia faba* L. cv. Salkim) was used as plant material. In the research, vermicompost (Brand was Ekosol, compost of *Eisenia foetida* species worms; pH was 6.5-8.5; organic matter was 35%, total N was 1.2%) and *Rhizobium leguminosarum* inoculant were used for fertilization of the crops. *Rhizobium leguminosarum* bacterium was obtained from "Soil Fertilizer and Water Resources Central Research Institute" (Ankara, Turkey) supplied in a peat media. No chemical fertilizer was applied.

Research soils were sampled at a depth of 0-30 cm prior to experiments and analysis were conducted. It was determined that trial area soil was clayey-loam structured, calcareous (1.61%), slightly alkaline (pH 7.6), salt-free (0.08 dS m^{-1}), weak in organic matter (0.90%), rich in potassium (669 kg ha^{-1}) and poor in plant available phosphorus content (31.2 kg ha^{-1}). (classification followed- and available phosphorus or P_2O_5 ??

The climatic data of the study area is given in Table 1. The average temperature in 2017 and 2018 growth seasons were higher than the long term averages. While the total amount of precipitation received in 2017 was higher than the long-term average, it was lower than the long-term average in 2018.

The trials were set up with three replications according to the randomized complete block design. Former crop was wheat for the trial field. Marker assisted hand sowings of broad beans was conducted in the first week of March on four rows at each parcel to 5 m long rows, with 30 cm inter-row and 10 cm intra-row spacing. Total 0, 400, 800 and 1200 kg ha^{-1} vermicompost were applied at once at pre-sowing stage just before incorporation with harrow and then irrigated with sprinkler. Plant seeds were soaked in water containing sugar at 4% concentration (İşler and Coşkan, 2009) and then were treated with *Rhizobium leguminosarum* bacteria (1 kg of peat culture/50 kg of seed) (Rivas *et al.,* 2009). Plants were grown under rainfed conditions. Weed control was done mechanically.

For observation and harvesting, border rows from each edges and 0.5 m from both ends of the plots were cut out. Observations were made on 10 plants selected from the remaining plants in parcels. Parcel harvest was conducted for yield determinations. The plants were harvested in the first week of July when the pods were dried and the grains got hardened. Harvesting and threshing processes were done manually. Plant height, first pod height, number of pods per plant, number of seeds per pod, 100-grain weight, and grain yield were investigated. The data were subjected to variance analysis and differences between the applications were determined by the $LSD_{(0.05)}$ test via JMP (version 5.0.1) software program.

RESULTS AND DISCUSSION

In the study, effects of the applications and years on all parameters were found statistically significant ($p<0.05$). The effect of Year x Application interaction on all properties was significant ($p<0.05$) except grain yield (Table 2 and Table 3).

Effect of precipitation was positive on plant growth. As mentioned by Uçar *et al.* (2020), plant available nitrogen mineralization in soil increases with increasing rainfall. Vegetative development of the plants (plant height and first pod height) was higher in 2017 compared to drier year 2018. This was similar to results obtained by Soysal and Erman (2020). Instead, the number of pods per plant, the number of seeds per pod, 100 grain weight and grain yield were higher in 2018 compared to 2017. The generative development of the plants was adversely affected in 2017 due to the anthracnose disease inspite of pesticide spraying. In particular, there was a opposite relationship between plant height, first pod height, number of pods per plant, number of seeds per pod, 100-grain weight and grain yield values. Plant heights were between 50.2-61.8 cm, first pod height were between 13.7-16.4 cm, number of pods per plant were between 6.37-8.99, number of seeds per pod was between 3.19-4.44, 100 grain weight was between 122.0-134.8 g and grain yield was between 1768-1907 kg ha^{-1}. The minimum values for all parameters were obtained from the control

Table 1: Meteorological data of experimental area.

Months	Monthly average temperature (°C)			Monthly total precipitation (mm)			Monthly average telative humidity (%)		
	2017	2018	Long year average	2017	2018	Long year average	2017	2018	Long year average
March	9.6	13.7	8.3	118.8	47.2	111.1	63.9	55.9	61.6
April	14.0	16.8	13.7	128.1	60.8	104.7	59.5	47.6	55.0
May	19.5	19.8	19.3	74.8	146.8	62.0	51.7	59.1	49.7
June	26.9	27.4	26.0	0.0	3.0	8.7	29.5	31.7	31.5
July	32.3	32.3	30.6	0.0	0.6	1.6	19.0	20.1	23.5
Total/ average	22.0	20.4	19.6	258.4	321.7	288.1	42.8	44.7	44.2

application. Maximum values for all parameters were obtained from *Rhizobium leguminosarum* + 800 kg ha^{-1} vermicompost application. However, there was no statistical significant difference between *Rhizobium leguminosarum* + 800 kg ha^{-1} vermicompost and *Rhizobium leguminosarum* + 1200 kg ha^{-1} vermicompost application. These were followed by applications of sole 1200 kg ha^{-1} vermicompost, combined application of *Rhizobium leguminosarum* + 400 kg ha^{-1} vermicompost, sole 800 kg ha^{-1} vermicompost, sole *Rhizobium leguminosarum and sole* 400 kg ha^{-1} vermicompost applications, respectively. As vermicompost dose increased, plant height, first pod height, pod number per plant, grain per pod, 100-grain weight, and grain yield were also increased. Soil organic matter has a role in increasing microbial activity in the soil. Since Siirt is within the borders of the gene center of the broad bean, naturally, *Rhizobium leguminosarum* bacteria exist in the soil. However, due to the low organic matter content of Siirt province and trial field soils, it is not possible to make a definite conclusion about the activities of bacteria under producer conditions. Under natural conditions, these bacteria infect plant roots. However, significant increases for all observed parameters by sole bacterial application reveal the requirement of repeated inoculations (Table 2 and Table 3).

Similar to this study, Roy and Singh (2006) reported that co-application of N-fixing bacteria + vermicompost increased grain yields. Also, Singh *et al*. (2012) observed increase in plant height by vermicompost applications. Bhattachariya and Chandra (2013) and Pezeshkpour *et al*. (2014) reported increased grain yields by vermicompost application. Kumar *et al*. (2014) determined increased plant height, pod number per plant, 100-grain weight and grain yield values by vermicompost applications compared to

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

Treatment	Plant height (cm)			First pod height (cm)			Number of pods per plant (pods plant^{-1})		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
Control	51.5	48.9	50.2 E	14.4	13.0	13.7 E	6.21	6.52	6.37 E
400 kg ha^{-1} VC	55.5	52.9	54.2 D	15.0	13.8	14.4 D	6.86	7.39	7.13 D
800 kg ha^{-1} VC	59.6	57.7	58.7 B	16.1	13.9	15.0 C	8.27	8.89	8.58 B
1200 kg ha^{-1} VC	62.7	60.5	61.6 A	16.6	14.9	15.8 B	8.45	9.16	8.81 A
R. leguminosarum	55.6	53.0	54.3 D	15.1	13.8	14.5 D	6.95	7.69	7.32 D
Rh. + 400 kg ha^{-1} VC	57.9	55.0	56.4 C	15.9	14.8	15.3 C	7.75	8.39	8.07 C
Rh. + 800 kg ha^{-1} VC	63.3	60.2	61.8 A	17.0	15.7	16.4 A	8.60	9.38	8.99 A
Rh. + 1200 kg ha^{-1} VC	63.0	60.2	61.6 A	16.9	15.5	16.2 A	8.53	9.13	8.83 A
Mean	58.6 A	56.0 B		15.9 A	14.4 B		7.70 B	8.32 A	
LSD$_{(0.05)}$ year		0.281*			0.275*			0.317*	
Treatment		0.841*			0.377*			0.221*	
Treatment × year		NS			NS			NS	

VC- Vermicompost; Rh- *Rhizobium leguminosarum;* *Significant at P≤0.05; NS- Non Significant at P>0.05.

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

Treatment	Number of seeds per pod (seeds pod^{-1})			100-grain weight (g)			Grain yield (kg ha^{-1})		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
Control	2.92	3.46	3.19 E	121.3	122.7	122.0 F	1759 h	1777 g	1768 G
400 kg ha^{-1} VC	3.24	3.88	3.56 D	122.7	124.5	123.6 E	1783 fg	1816 e	1799 F
800 kg ha^{-1} VC	3.55	4.16	3.86 C	126.8	127.7	127.3 C	1829 d	1873 b	1851 C
1200 kg ha^{-1} VC	3.81	4.24	4.03 B	129.2	131.3	130.3 B	1849 c	1877 b	1863 B
R. leguminosarum	3.30	4.01	3.66 D	123.5	124.8	124.2 E	1790 f	1828 d	1809 E
Rh. + 400 kg ha^{-1} VC	3.49	4.18	3.84 C	125.2	126.3	125.8 D	1821 de	1853 c	1837 D
Rh. + 800 kg ha^{-1} VC	4.11	4.76	4.44 A	133.3	136.2	134.8 A	1881 b	1934 a	1907 A
Rh. + 1200 kg ha^{-1} VC	4.10	4.61	4.36 A	133.1	135.2	134.2 A	1874 b	1931 a	1903 A
Mean	3.56 B	4.16 A		126.9 B	128.6 A		1823 B	1861 A	
LSD$_{(0.05)}$ year	0.037	0.242	3.373						
Treatment	0.146	0.933	7.486						
Treatment × year	NS	NS	10.587						

VC- Vermicompost; Rh- *Rhizobium leguminosarum;* *Significant at P≤0.05; NS- Non Significant at P>0.05

control. Pashaki *et al.* (2016) stated that microbial fertilizer and vermicompost application increased the number of pods per plant, the number of grains per pod, and the grain yield compared to the control. Similar results were also reported by Mohammadi and Rezaei (2019) for the broad beans at different locations.

CONCLUSION

As a results of this study, application of 800 kg ha^{-1} vermicompost with *Rhizobium leguminosarum* inoculation and application of 1200 kg ha^{-1} vermicompost with *Rhizobium leguminosarum* inoculation were found superior for higher grain yields in broad bean. As the dose of vermicompost increased, plant height, first pod height, pod number per plant, number of seed per plant, 100-seed weight, and grain yield were also increased. All parameters were lowest in control. According to the results of this study, for highest grain yield in broad bean cultivation in Siirt province conditions without any chemical fertilizer application, *Rhizobium leguminosarum* inoculation + 800 to 1200 kg ha^{-1} vermicompost application is recommended.

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