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Original Article

Effects of bacteria and vermicompost on morphological characteristics and yield of soybean (Glycine max L.) in sustainable agricultural systems

Mona Kazemi Moghadam[1], Hossain Hassanpour Darvishi[1*], Mohsen Javaheri[2]

[1]Department of Agronomy, College of Agriculture, Shahr-e-Qods Branch, Islamic Azad University, Tehran, Iran
[2]Department of Agronomy, College of Agriculture, Sanandaj Branch , Islamic Azad University, Sanandaj, Iran

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A B S T R A C T

Objective: Investigating the microbes and interactions of the beneficial symbiotic relationships between the components of the system ecology in the food chains and life cycles is one of the modern sustainable agriculture topics. In this regard, to evaluate the effects of bacteria and vermicompost on morphological characteristics and yield of soybean an experiment was conducted as split plot in a completely randomized block design with three replications. **Methods:** Main plots of experiment were at two levels including the non-use and the use of bacteria and the subplots were at three levels including the non-use of vermicompost (control), the use of 5 tons of vermicompost per acre and the use of 10 tons of vermicompost per acre. **Results:** The results of mean comparison showed that the treatment including 10 tons of vermicompost had the highest amount of oil content (11%) and the lowest amount was obtained from the treatment including use of 5 tons with the amount of 9.77%. Increasing the seed growing and filling period led to obtain the highest amount of seed yield with the amount of 1699 kg ha while the lowest amount of seed yield was obtained from the treatment including non-use of vermicompost with the amount of 1419 kg ha. The use of bacteria compared with non-use of it led to obtain the highest amount of seed yield with the amount of 1636 kg ha while non-use of bacteria had the lowest amount of seed yield with the amount of 1443 kg ha. Also, the results showed that the plants at the flowering stage had the highest amount of relative water content and chlorophyll of leaf by use of 10 tons of vermicompost while in the seed filling stage the treatment including the use of 5 tons of vermicompost had the highest amount of RWC.

1. INTRODUCTION

Soybean (Glycine max L.) is widely used for human and livestock and poultry for adaptation to different climatic conditions, high protein and oil production and various usages (Aliari et al., 2000). Sustainable agriculture is a biological process that tries to implement the key characteristics of a natural ecosystem. In this approach, the main objective is the long-term strengthening and increase of soil fertility, biological control of pests and diseases, reducing or eliminating chemical fertilizers and fertilizer materials. In recent years, the need to study the biological characteristics of root growth area is significantly considered for the sustainable agriculture in order to improve the nutrition and growth of the plant. The importance of biological nitrogen fixation in soybean and Rhizobium Japonicum bacteria is known by a number of researchers who examine various aspects of this relationship. After infection of soybean roots by Rhizobium Japonicum, the node is made in the outer shell

***Corresponding Author:** Hossain Hassanpour Darvishi, Department of Agronomy, College of Agriculture, Shahr-e-Qods Branch, Islamic Azad University, Tehran, Iran (hhassanpour87@gmail.com)

of the root and the bacteria lead to the creation and growth of the node by producing auxin and cytokinin. Tejada and Gonzalez (2008) reported the decrease of soil bulk density and increase of soil porosity by the use of organic fertilizers of compost, vermicompost and livestock manure in the soil and the highest effect was attributed to Compost. During an experiment by using vermicompost in soil, Mirzaee et al (2009) also stated that this type of fertilizer makes the soil spongy and increases the percentage of pores nd ultimately reduces the soil bulk density. Safar Zadade et al (2007) reported that the world's attention to modern agriculture and applying the new sciences and technologies is considered to minimize the damage to resources and maximize the utilization of them; however, using the growth regulators has attracted many researchers to improve the crop growth and increase their production. Asadi et al (2000) reported that for the plants like soybeans that can have the highest yield by the symbiosis dependence to molecular nitrogen-fixing bacteria without need to the use of synthetic fertilizers. Using this substantial ability is considered as an inevitable necessity in terms of its helpful economic and environmental aspects. Today, the use of organic fertilizers is not very common for various reasons, while according to the reports, using it increase the plant stability in the soil, in addition to maintain the nutrient cycle, reduce the pollution and modify the physico-chemical properties of soil and in this regard, the effect of organic fertilizers is beyond the pure chemical fertilizers (Magdoff and weil, 2004). The use of bio-fertilizers like vermicompost, microorganisms solubilizing phosphate and Azotobacter in a system based on organic farming enhances the quality and stability of the yield while maintaining environmental health (Sharma 2002). The organic matter is the main cause of soil productivity and fertility and for maintaining the fertility and productivity of soil the organic matter level must be maintained at an appropriate level.

Apart from providing nutrients, the organic matters have the different effects on the soil properties, especially its physical properties (Pedra, et al, 2006). In an experiment on the pea, it is found that the use of 3 t ha of vermicompost significantly increased the seed yield and biological yield compared with the control (jat and Ahlawat, 2004). By investigating the combined use of organic fertilizers on soybean, Maheshbabu et al (2008) found that the seed yield with the combined use of vermicompost + livestock manure (50 per cent) was significantly increased compared to carbide of either alone (100%). Also the study of Manna et al (2003) about vermicompost showed that the soil biological activities including soil respiration, microbial carbon biomass and dehydrogenase activities in vermicompost treatments were much more than treatments containing chemical fertilizers.

2. MATERIALS AND METHODS

The research was conducted in 2012-2013 in the agricultural research farm, located at 2 km from the city of Sanandaj with the geographical position of 46 degrees, 29 minutes longitude and 35 degrees, 16 minutes latitude, with the altitude of 1393 meters above sea level as split plot in a completely randomized block design with three replications. The main plots of experiment were at two levels including the non-use and the use of bacteria and the subplots were at three levels including the non-use of vermicompost (control), the use of 5 tons of vermicompost per acre and the use of 10 tons of vermicompost per acre. The bacterium used was Bradyrhizobium Japonicum, the vermicompost used contained the worms called Eisenia foetida and also the cultivar used was Safiabad cultivar. Every experimental plot had 6 plant lines with the long of 3 m, the distance between the rows was 50 cm and the distance between the plants on the row was 10 cm. For moistening the seed, a solution of 10% sucrose and the bacteria was used for the seed in the shade and immediately after that the planting was done. Also for analyzing the physical and chemical properties of experiment area soil before preparing the ground, some points from zero to thirty-cm depth were sampled (Table 1).

The physiological characteristics including the chlorophyll and relative water content (RWC) at two flowering stages (the first stage) and seed filling stage (second stage) and also the characteristics related to yield and yield components including the number of pods per plant, 100 seed weight, seed yield and oil content were evaluated. The device SPAD-520 manufactured by Minolta Company of Japan was used to measure the leaf chlorophyll. Also, to measure the relative water content of leaf three discs from each leave were taken with dimensions of 20 mm from the selected plant per plot and were weighed immediately (wet weight). Then, the samples were distilled twice for 4 h in distilled water at about 5° C and little light (until stabilization of water absorption and weight gain) and weighed after taking the water over them with filter paper (weight of full swelling). Then, the samples were put in the oven for 24 h at 80° C and weighed (dry weight). Finally, RWC was calculated from the following equation. The statistical calculations related to the analysis of variance and the mean comparison was conducted by using my software MSTAT- C and mean comparisons of the characteristics were plotted by Duncan's multiple range test and the graphs were plotted by using software Excel.

Table 1.

Physicochemical test results of soil of experiment area

Electrical Conductivity	Acidity	Sand	Silt	Clay	Organic carbon	Total nitrogen	Absorbable phosphorous	absorbable Potash
EC*104	(PH)	(%)					(ppm)	(ppm)
1.283	7.5	64.6	26	9.4	1.07	0.107	11.7	120

3. RESULTS AND DISCUSSION

Results obtained from analysis of variance showed that there was a significant difference in the plant height, stem diameter and oil content at the level of 1% of vermicompost treatment so that the mean comparisons of characteristics by Duncan's test at the level of 5% showed that the highest amount of plant height was obtained from the treatment including the non- use of vermicompost with the amount of 74.67 cm and the lowest amount was obtained with the amount of 57.44 cm from the treatment including the use of 10 tons of vermicompost (Table 3).

Yazdani et al (2008) reported that using the different organic matters has not made a significant difference in the length and weight of stem. The seedling weight and number of nodes significantly increased affected by the application of trash compost and livestock manure compared to the control and vermicompost. Then the results showed that the highest and the lowest amount of stem diameter and plant height were obtained from the treatments including the non-use of vermicompost and the use of 10 tons of vermicompost for stem diameter and plant height, respectively, that it shows the effects of the treatment including use of vermicompost for reducing the growth of lateral shoot and plant height in order to increase the economic output or seed yield as the highest amount of seed yield was obtained with the amount of 1699 kg ha from the treatment including the use of 10 tons per hectare of vermicompost while the lowest amount of seed yield was obtained with the amount of 1419 kg ha from the treatment including the non-use of vermicompost that was consistent with the results of Malecoti and Homaei (2004) who stated that the use of organic fertilizer leads to increase the soybean yield by providing phosphorus and most micronutrients that resolving the micronutrients deficiency by organic matters is presented due to the complexing strength of the material. The use of bacteria led to achieve the highest seed yield with the amount 1636 kg ha compared with lack of using bacteria while the lack of using bacteria had the lowest amount of seed yield with the amount of 1443 kg ha.

Table 2.
Variance analysis of the characteristics

Sources of changes	Degree of freedom	Mean squares									
		Plant height	Stem diameter	Leaf chlorophyll in flowering stage	Leaf chlorophyll in seed filling stage	RWC in flowering stage	RWC in seed filling stage	Number of pod per plant	100 seed weight	Seed yield	Oil content
Repetition	2	98.838 ns	0.053 ns	5.774 ns	17.038 ns	7.0706 ns	543.948 ns	22.389 ns	0.256 ns	8448.222 ns	0.140 ns
Bacterium	1	307.024 ns	14.293 **	48.020 ns	17.268 ns	0.006 ns	00.32 ns	46.722 ns	0.100 ns	172480.222 ns	2.311*
Error	2	655.359 ns	0.174 ns	72.605 ns	4.203 ns	16.211 ns	49.831 ns	4.389 ns	0.530 ns	233798.222 ns	0.070 ns
Vermicompost	2	445.665**	10.538**	13.342 ns	14.383 ns	19.120 ns	8.290 ns	95.722 *	0.582 ns	220438.389 *	2.383**
Bacterium*vermicompost	2	12.53 ns	1.766*	62.647 ns	41.983 ns	31.277 ns	48.750 ns	70.056 ns	0.987 ns	72287.056 ns	8.683**
error	8	53.648 ns	0.266 ns	24.517 ns	22.107 ns	78.327 ns	41.084 ns	22.722 ns	1.188 ns	47164.556 ns	0.071 ns
Coefficient of variations (%)		11.12	7.73	14.57	16.97	17.49	12.27	15.74	8.73	13.10	2.56

Ns, * and ** indicate the lack of significant difference and the significant difference at the level of 5% and 1%, respectively.

Ghorbani Nasr Abadi et al (2002) reported that the mean comparison of treatments inoculated and non-inculated by Bradyrhizobium Japonicum bacterium shows that inoculation with this bacterium has significantly increased the indices of soybean growth and the number of nodes of root system and nitrogen-fixation. Also, the characteristics of the pod per plant and seed yield had a significant difference at 5% level under the influence of the treatment including the use of vermicompost. In the interactions the bacteria and vermicompost were located in the same statistical group so that the highest amount of seed yield was obtained with the amount of 1731 kg ha from the treatment including the use of bacteria and vermicompost with the amount of 10 tons while the lowest amount of seed yield was obtained with the amount of 1311 kg from the interaction between control treatments (non-use of bacteria and vermicompost) that shows the effects of using vermicompost and bacteria as a factor enhancing economic yield in order to achieve the stability in the soybean nutrition. Also, the bacteria used have provided the optimum plant growth conditions by nitrogen-fixing to the extent required. Then, the results of analysis of variance showed that there was a significant difference in stem diameter of the treatment of interactions between bacteria and vermicompost at the level of 5% so that the highest amount of stem diameter was obtained from the interactions between the non-use of bacteria (control) and the use of 5 tons ha of vermicompost. Then the highest amount of 100 seed weight was obtained from the treatment including the use of 10 tons of vermicompost with the amount of 12.95 kg ha. In the interactions, the highest amount of leaf chlorophyll in the flowering and grain filling stages as well as the highest amount of leaf chlorophyll in both the flowering stages were obtained from the interactions between the treatment including non-use of bacteria and the use of 10 tons ha of vermicompost that showed an increase in the photosynthetic activity of plant in optimal conditions to achieve higher yield.

Table 3.
Mean comparison of the characteristics

treatment											
Effect of bacterium	vermicompost	Plant height (cm)	Stem diameter (mm)	Leaf chlorophyll in flowering stage (%)	Leaf chlorophyll in seed filling stage (%)	RWC in flowering stage (%)	RWC in seed filling stage (%)	Number of pod per plant (N)	100 seed weight (g)	Seed yield (kg ha)	Oil content (%)
Non-use of bacterium		61.74a	8.85a	35.61a	32.90a	50.63a	51.44a	31a	12.53a	1443a	10a
use of bacterium		70b	9.33b	32.34b	27.68b	5.59a	53.05a	34b	12.68a	1636b	10a
	Non-use of vermicompost	74.67a	9.830a	32.67a	26.10b	51.59a	50.93a	39.50a	12.52a	1419a	10.47b
	use of 5 tons of vermicompost	57.44b	9.722a	33.67a	25.54b	48.55a	53.20a	36.50a	12.35a	1502a	9.775c
	use of 10 tons of vermicompost	65.50ab	7.720b	36.50a	39.24a	51.69a	52.60a	36.67a	12.95a	1699a	11.03a
Bacterium* vermicompost											
Non-use of bacterium* Non-use of vermicompost		72ab	9.053b	32.87ab	24.81b	50.65a	50.88a	24.33c	12.81a	1311a	11.17b
Non-use of bacterium* use of 5 tons of vermicompost		53.22c	10.94a	33.03ab	22.55b	46.92a	49.24a	34b	11.84a	1352a	9.667c
Non-use of bacterium* use of 10 tons of vermicompost		60bc	6.553c	40.93a	51.34a	54.31a	54.20a	43.33ab	12.94a	1667a	9.367c
use of		77.33a	10.61a	32.47ab	27.39b	52.53a	50.98a	48.67a	12.22a	1526a	9.767c

bacterium* Non-use of vermicompost											
use of bacterium* use of 5 tons of vermicompost		61.66bc	8.500b	34.30ab	28.53b	50.17a	57.15a	39.33ab	12.85a	16.52a	9.883c
use of bacterium* use of 10 tons of vermicompost		71ab	8.887b	30.27b	27.13b	49.06a	51.01a	11.02d	12.96a	1731a	12.70a

In each column, the means that have at least one common letter are in the same statistical group with the Duncan test at 5% level.

CONCLUSION

Longer soybean growth stages due to using vermicompost shows the availability of appropriate opportunity and conditions for plant growth. The plant growth promoting bacteria also improve the plant growth by producing the hormones stimulating the plant growth and increasing the root uptake efficiency. Considering the results obtained the positive effects of using the bacteria restricting the growth can be considered as a factor in increasing the stimulation of vegetative and reproductive growth of soybean.

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