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THE EFFECTS ON THE ROOT AND PLANT DEVELOPMENT OF SOYBEAN OF ORGANIC FERTILIZER APPLICATIONS

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Abstract

Organic fertilizers increase soil aeration, water and nutrient holding capacity, improve seed germination and encourage the production of thicker roots, increase the yield and quality of the crop. This study was aimed to determine the effects of organic fertilizer (vermicompost, sheep manure, cattle manure, poultry manure and inorganic fertilizer as control) applications on the root and plant development of soybean during two growth stages, namely third trifoliate stage (V3) and beginning of flowering of the plants (R1) in the pot condition. The experiment was established with a two-factorial randomized plot design with four replications. The fertilizer applications had a significant effect ($p<0.01$) on the V3 and R1 growth stages of soybean. The highest plant height (36.78 cm) and root length (41.18 cm) were achieved with vermicompost, and the lowest plant height (21.73 cm) was recorded with inorganic fertilizer. The number of nodules was highest for vermicompost and cattle manure applications (17.16 plant^{-1} and 16.76 plant^{-1}, respectively), and lowest for poultry manure (0.22 plant^{-1}). In the R1 growth stage, poultry manure produced the highest biological fresh and dry weights, root dry weight at 25.08 g plant^{-1} and 5.67 g plant^{-1}, 3.99 g plant^{-1} respectively. As a result, it was demonstrated that vermicompost and poultry manure applications promote strong root and plant development due to high organic matter and phosphorus and can be used successfully without inorganic fertilize application in soybean farming.

Keywords: Growth stages. Nodule. Poultry manure. Soybean. Vermicompost.

1. Introduction

Soybean is an important crop that contains 36 - 40% protein, 18 - 24% fat, 26% carbohydrate and 8% minerals in its seeds (Wijewerdana et al. 2019). It is one of the largest sources of vegetable oil and protein for humans and is also a high-quality animal food (Carciochi et al. 2019; Kakabouki et al. 2020), especially for poultry (Erdaw et al. 2016).

In 2019, 150 000 tons of soybean was produced on an area of 25 295 ha in Turkey. Annual consumption of soybean in Turkey for vegetable oil and animal feed purposes is 2 200 000 tons. However, as production falls well short of demand, approximately 2 271 000 tons of soybean and meal are imported yearly (TUIK 2020). With each passing day, the increase in both vegetable oil consumption and poultry production increases the demand for soybean products (Gul and Arslanoglu 2020).

Organic fertilizers (OFs), which are carbon-based compounds that increase the growth and productivity of plants, are natural materials of either plant or animal origin. They include blood, horn and hoof powders; fish and bone meals; rock phosphate and wood ash, manure from livestock such as cows, chickens and goats (Sharma and Chetani 2017), horse and sheep manure, crop residues, household waste, compost and green manures (Gupta and Hussain 2014). The repeated use of OFs increases soil organic matter levels (Hammed et al. 2019), improves water infiltration and aeration of the soil (Mujdeci et al. 2020), is relatively less costly, increases development of plant thicker roots (Nagavardhanam 2017) and enhances soil biological activity as organic materials decompose (Ahmadpour and Armand 2020). The proper handling of OFs enhances their quality and effectiveness (Martey 2018), and they do not leave residues (Pereira et al. 2020). Organic fertilizers help to prevent diseases by meeting plants nutritional needs (Bhatt et al. 2019). Therefore, the correct use of OFs can play a leading role in achieving sustainability in agricultural production and increasing soil fertility (Thomas et al. 2019). They also increase the yield and quality of crops in ways similar to inorganic fertilizers (Bhatt et al. 2019), when properly applied, they can partially or totally replace inorganic fertilization (Ragagnin et al. 2013). Properly applied OFs can partially or totally replace process of inorganic fertilization (Zerihun and Haile 2017; Ahmadpour and Armand 2020).

Organic manure is a part of the organic cycle and is available at no additional cost to farmers who have livestock (Leipa et al. 2019). Across the world, the average price of organic soybean is 15% to 30% higher than the price of traditionally produced soybean (Olewe et al. 2014). Organic soybean production has been confirmed to be a profitable venture; research showed that organic fertilizer uses significantly increased productivity and income by 1.43 times (Martey 2018). The use of OFs, especially to produce feed for organic chicken and egg production, is both practical and beneficial to enterprises that produce large quantities of manure or have access to it at low cost. At present, the use of OFs is practically non-existent (Thomas et al. 2019) or minimal in soybean farming. However, soybean is very efficient at exploiting the prolonged effects of farmyard manure application (Crnobarac et al. 2011). Organic fertilizer applications produced high yield in soybean by increasing nodulation, the highest bean number, and seed yield (Gautam and Pathak 2014).

The hypothesis of this study; have positive effects on the root and plant growth of vermicompost, sheep manure, cattle manure and poultry manure applications in soybean cultivation and they can be as a substitute for inorganic fertilizer. So, it was aimed to compare with inorganic fertilizer application and to determine the effects of vermicompost, sheep manure, cattle manure, poultry manure applications on the root and plant development of soybean during V3 and R1 growth stages growth in pot conditions.

2. Material and Methods

The soybean variety Arisoy was used in experiment. It has at III. Maturity Group (105-110 days), white flower and red-brown hilum, average plant height of 116 cm and average seed yield of 4340 kg ha^{-1}, containing 37 % protein and 19 % oil (Gul and Arslanoglu 2020).

Organic fertilizer: the poultry manure and the vermicompost manure from a commercial companies; sheep and cattle manure from local husbandry enterprises selling separated and matured manures were bought. All of the manures used were in the solid form. The chemical contents of the organic fertilizers were determined with laboratory analysis and shown at Table 1.

Table 1. Chemical contents of organic fertilizers.

Organic manure	pH	OM (%)	Total N (%)	Total P (%)	Total K (%)	MO (%)
Vermicompost (VC)	7.5	40	1.5	1.2	0.6	30
Sheep manure (SM)	7.1	38	2.1	0.5	0.9	20
Cattle manure (CM)	7.9	37	1.1	0.6	0.4	20
Poultry manure (PM)	6.5	52	3.2	2.2	1.7	20

OM: organic matter, N: nitrogen, P: total phosphorus, K: total potassium, MO: moisture content

In the experiment, roundish 10 L capacity of black seedling production pots (26 cm diameter and 25 cm height) were used. The clay soil used in the fertilizer-soil mixtures was of neutral (pH: 7), slightly calcareous ($CaCO_3$, 1.22 %), slightly saline (3.053 mmhos cm^{-1}), of moderate organic matter content (2.71 %), very high in P_2O_5 (293 mg/l) and low in K_2O (10.34 mg/l).

The experiment was conducted with a two-factor randomized plot design, with 4 repetitions. In this research two factors were examined, namely organic fertilizer (OF) (vermicompost, sheep manure, cattle manure, poultry manure, inorganic fertilizer as a control) and growth stages (V3 and R1). The V3 growth stage indicates third trifoliate stage, with three nodes on the main stem with fully developed leaves, beginning with the unifoliolate node. The R1 growth stage was beginning of flowering of the plants (Nleya et al. 2013; Gabardo et al., 2021).

Total 120 kg ha^{-1} nitrogen (N) application as inorganic fertilizer is recommended for the soybean farming (Kilinc and Arioglu 2018). For this reason, at the control pots applied inorganic fertilizers; first application was done at the sowing time (50 kg ha^{-1} N), 15-15-15 (N-P-K) in the form of compound fertilizers; second application at the beginning of flowering (70 kg ha^{-1} N), in the form of 33 % N ammonium nitrate. The inorganic fertilizer was not given to organic fertilizer application pots. Organic fertilizer amounts were calculated by using the total N amount of the manures (Table 1) and equaling 120 kg ha^{-1} N. The volume of the pot was also taken into account in this calculation. The calculations were made as follows:

Vermicompost application: 500 g vermicompost + 9500 g soil pot^{-1}

Sheep manure application: 357 g sheep manure + 9643 g soil pot^{-1}

Cattle manure application: 680 g cattle manure + 9320 g soil pot^{-1}

Poultry manure application: 235 g poultry manure + 9765 g soil pot^{-1}

After the soil and fertilizer amounts for each application was determined, they were mixed separately for each application and pot. Then the pots were filled, and the organic fertilizers were applied to pots at once with sowing. Each fertilizer application was conducted in 8 pots (4 pots for V3 growth stage and 4 pots for R1 growth stage).

Soybean seed inoculation was required for soybean farming due to absence of *Bradyrhizobium japonicum* is in Turkey' soils. Fifteen seeds were sown equidistantly at 3-4 cm depth in each pot, on May 1, 2019, after the seed batch had been inoculated at a dose of 50 g kg^{-1} of seeds with a commercial inoculant of *Bradyrhizobium japonicum* produced by the Soil Fertilizer Central Research Institute, Ankara-Turkey and containing $5x10^9$ colony forming units per gram. After emergence, the plants were thinned out by keeping the strongest 10 plants in each pot. All observations and measurements were conducted at V3 and R1 growth stages of these 10 plants in each pot. The pots were placed in an open area in a field (41° 37′ 24.71″ N, 36° 21′ 11.02″ E and 137 m altitude) at the Research and Experiment Field of Faculty of Agriculture, Ondokuz Mayis University, Turkey. Where they had a completely natural growing environment from planting to harvesting in a location where they could make full use of the available sunlight. During the experiment, the air temperature ranged between 10 °C and 32 °C, and the relative humidity ranged between 53 % and 87 %, the plants were irrigated daily for water requirement.

Harvesting and measurements were completed on June 14, 2019 exactly after 44 days after sowing (DAS) for the V3 growth stage and on July 28, 2019 (88 DAS) for the R1 growth stage. During harvesting, the plants and the soil was removed from the pot and placed on a 2 mm mesh sieve. Next, the soil was washed from the roots through the sieve, and the nodules were detached and counted. The plant height and root length were measured per plant, cutting from root collar and separated above ground part of plant and root from each other. The biological fresh weight (g $plant^{-1}$) was determined by weighing the above ground part of the per plant, and the root fresh weight (g $plant^{-1}$) by weighing the root part. Plant height (cm) was determined distance from the root collar to the tip of the plant. The root length (cm) was measured as the distance from the root collar to the tip of the longest root. The nodule number (number $plant^{-1}$) was counted per plant. Then, samples were dried in a ventilated oven at 80 °C for 48 hours for determination of the root dry weight (g $plant^{-1}$) and biological dry weight (g $plant^{-1}$), then they were taken weight (Brdar-Jokanović et al. 2014).

All the data obtained were analysed using analysis of variance (ANOVA) in accordance with the two-factorial experimental design by using the MSTAT-C statistical package programme. Differences between means were compared by Least Significant Difference (LSD) at level of $p<0.01$, using statistical procedures recommended by Gomez AV and Gomez AA (1984).

3. Results and Discussion

The root length significantly ($p<0.01$) affected by the growth stages (GS), fertilizer applications (FA), but was not found significant for their interaction (GS x FA) ($p<0.01$). The mean root length (RL) was greater in the R1 GS (41.49 cm) than in the V3 GS (32.97 cm), with the longest roots produced with vermicompost application (41.18 cm) followed by the inorganic fertilizer (38.54 cm) and sheep manure (38.39 cm). The root length was shortest (33.99 cm) with cattle manure application (Table 2).

Table 2. The Effects of Organic Fertilizer Applications (FA) on the Root Length (RL), Plant Height (PH) and Nodule Number (NN) of Soybean at the V3 and R1 Growth Stages (GS).

		Root Length (cm)			Plant Height (cm)			Nodule Number ($plant^{-1}$)		
		V3	R1	Mean	V3	R1	Mean	V3	R1	Mean
Vermicompost		38.00	44.37	41.18^{A}	21.64^{d}	51.92^{a}	36.78^{A}	1.76^{d}	32.57^{a}	17.16^{A}
Sheep manure		34.76	42.03	38.39^{AB}	18.72^{d}	40.80^{b}	29.76^{B}	1.83^{d}	22.20^{b}	12.01^{B}
Cattle manure		31.74	36.25	33.99^{B}	21.02^{d}	40.72^{b}	30.87^{B}	3.97^{d}	29.55^{a}	16.76^{B}
Poultry manure		28.88	39.21	34.04^{B}	19.02^{d}	46.03^{b}	32.52^{B}	0.00^{d}	0.45^{d}	0.22^{D}
Control		31.48	45.59	38.54^{AB}	15.95^{d}	27.52^{c}	21.73^{C}	4.90^{d}	11.17^{c}	8.03^{C}
Mean		32.97^{B}	41.49^{A}		19.27^{B}	41.40^{A}		2.49^{B}	19.19^{A}	
CV			8.86			9.46			23.66	
LSD	GS		4.058**			3.565**			3.155**	
	FA		4.538**			3.986**			3.528**	
	GS x FA		ns			5.637 **			4.989**	

The difference between the averages indicated by the same letter in the same group is not statistically significant, **: Significant difference at P<0.01 level, CV: Variation coefficient, LSD: Least Significant Difference, ns.:non significant

The growth and development of the soybean root system is linked to the stages of development of the above ground plant parts and there are five growth stages of soybean root system development: namely early vegetative growth (VE-V6), pre-flowering period (V6-R1), flowering (R1-R3), pod formation and growth (R3-R4), and seed growth and maturity (R5-R6). In the early vegetative GS, the roots grow much faster than the above ground plant parts, with daily growth in length of 2.5 cm to 5 cm. The major mass of soybean roots is in the top 15 cm of the soil. In the pre-flowering period, the growth of the main roots slows down but the total dry root weight (RDW) increases. The total RDW continues to increase during all vegetative stages, including the flowering stage. However, after this period, it increases slowly (Miladinovic and Dordevic 2011).

The data from the present study showed that soybean roots grew quickly until the V3 GS of but slowed between the V3 and R1 GSs (Table 2), as reported by Miladinovic and Dordevic (2011). In earlier studies, it has been demonstrated that high N content in the soil is the most critical factor affecting all root growth parameters and its high N negatively influences root growth in soybean (McCoy et al. 2018). In the present study, among the fertilizer applications the longest roots were produced with vermicompost application (total N, 1.5 %), it was followed by sheep manure and inorganic fertilizer applications. Overall, Blouin et al. (2019) stated that vermicompost manure helps roots to develop better, thereby increasing plant height, root development. Moreover, it can be increased water retention capacity by improving soil structure. Thus, it promotes rapid plant growth.

The plant height was significantly ($p<0.01$) affected by growth stages (GS), fertilizer applications (FA) and their interaction (GS x FA) (Table 2). The maximum mean plant height (PH) among fertilizer applications was measured for vermicompost (36.78 cm), and the inorganic fertilizer (control) produced the lowest height (21.73 cm). In addition, the PH was similar at all fertilizer applications in the V3 GS while the greatest plant height (51.92 cm) was measured for vermicompost application in R1 GS (Table 2).

Kuntyastuti et al. (2018) who reported no significant difference in soybean plant height at 40 days after planting for four manure applications (V3 measurements were made on day 44 in the present study) and Miladinovic and Dordevic (2011) reported that plants primarily form roots in the V3 GS.

Moghadam et al. (2014) reported that vermicompost use (10 ton $acre^{-1}$ or 25 ton ha^{-1}) in soybean cultivation had a positive effect on plant growth and seed yield. Specifically, it increased plant height ($p<0.01$) and also increased the days to flowering ($p<0.05$). Similar results were reported by Mamia et al. (2018) who determined that the greatest plant height was produced with vermicompost and inorganic fertilizer mixtures. Devi et al. (2013) stated that the application of organic fertilizer improved the pH and organic carbon levels of the soil and that organic manure application reduced chemical fertilizer use. They reported that with farmyard manure (5 ton ha^{-1}) and vermicompost (1 ton ha^{-1}) applications for soybean, mean plant heights of 32.70 cm and 33.34 cm, respectively. Gul and Arslanoglu (2020) stated that the greatest plant height was obtained from chicken manure application. While in another study the greatest plant height (112.64 cm) was achieved with cattle manure, while the shortest plants (87.83 cm) were the control plants; more specifically, 1500 kg ha^{-1} of cattle manure application was found to be significant (Cevheri and Yilmaz 2018). In our study, root development increased with vermicompost application, which also increased plant height.

The growth stages (GS), fertilizer applications (FA) and their interaction (GS x FA) were significant ($p<0.01$) in terms of number of nodules (Table 2). The highest mean number of nodules (NN) was achieved with the vermicompost and cattle manure applications at 17.16 $plant^{-1}$-16.76 $plant^{-1}$, respectively, and the lowest number resulted from the poultry manure application (0.22 $plant^{-1}$) among the applications. The number of nodules was significantly lower in V3 GS (2.49 $plant^{-1}$) than in the R1 GS (19.19 $plant^{-1}$) (Table 2). The number of nodules was similar in V3 GS of the plant for all fertilizer applications; nodule was not formed by poultry manure application and nodule number of control plant (4.90 $plant^{-1}$) was found higher at V3 GS. However, in the R1 GS, number of nodules was significantly higher for the vermicompost and cattle manure applications (32.57 $plant^{-1}$ and 29.55 $plant^{-1}$, respectively) (Table 2).

Soybean plants have a symbiotic relationship with nitrogen-fixing *Brady rhizobium japonicum* bacteria (Yuan et al. 2020) and this bacteria has a positive effect on the nodule formation, plant growth and yield of soybean after inoculation. Nodules are visible 7 to 9 days post-inoculation (Miladinovic and Dordevic 2011) and the most active stage was between the beginning of flowering and the seed filling stage during 3-4 weeks after germination. At four weeks post-inoculation, the nodules reach full size, with one plant able to host a few hundred nodules (Purcell et al. 2014). Soybean uses nitrogen in the soil only in the short period between when it stops using its cotyledons for nutrition and during the time of formation of nodules. This period lasts for first two to three weeks of growth and development (Crnobarac et al. 2011). The inadequacy of available N frequently causes slow plant growth, susceptibility to disease, inefficient water uses and poor yield of low quality produce (Mandi'c et al. 2020). Excessive N reduces root growth and increases vegetative growth and roots become shorter and thicker. Moreover, excessive N directly inhibits nodule formation in soybean (Khan et al. 2020). Furthermore, increasing N rates reduce the number of nodules, so that ultimately no nodules are formed on the roots of soybean (Crnobarac et al. 2011).

In the present research, in the V3 GS (including the 4^{th} week), when nodule formation had just started, and no significant difference was found between applications in the number of nodules. There were no nodules on the plants in the poultry manure treated pots in the V3 GS, and they had the lowest number of nodules for all treatments in the R1 GS, too. However, significant differences were found between fertilizer applications in the R1 GS, with the highest number of nodules in the vermicompost (1.5 % N) and cattle manure (1.1 % N) applications, 32.57 $plant^{-1}$ and 29.55 $plant^{-1}$ in the R1 GS, respectively. In our study, as stated in the aforementioned research, the high N (3.2 %) and high organic matter (OM) content (52 %) of poultry manure probably prevented nodule formation (Table 1-2).

Abbas et al. (2011) who reported that 75 days after planting, the highest number of nodules in soybean was in the 48 m^3 ha^{-1} farmyard manure (FMY) application, with the lowest number of nodules in the 167 kg N ha^{-1} chemical fertilizer application. Our study results of support those of other researchers (Crnobarac et al. 2011; Ciampitti and Salvagiotti 2018) in that N-deficient plants formed more nodules to meet their N demand.

Since this research was terminated at the end of the R1 stage, no information is available on the relationship between nodule formation and manure in subsequent growth stages. But, the highest weights were obtained for RDW and BDW with poultry manure application (Tables 3, 4), and plants with high dry matter content could be expected to have high seed yields; Gul and Arslanoglu (2020) reported that because poultry manure application increased seed yield in second crop soybean production, it could be substituted for inorganic fertilizers.

The biological fresh and dry weight significantly ($p<0.01$) affected by growth stages (GS), fertilizer applications (FA) and their interaction (GS x FA) (Table 3). The mean biological fresh weight (BFW) was higher in the R1 GS (19.09 g $plant^{-1}$) than in the V3 GS (5.66 g $plant^{-1}$). The highest BFW was for vermicompost (15.68 g $plant^{-1}$), followed by poultry manure (15.37g $plant^{-1}$) and sheep manure (13.72 g $plant^{-1}$), while the lowest BFW was for control application (7.42 g $plant^{-1}$). For interaction between GS and FA, the lowest mean BFW measured of control plants (2.70 g plant^{-1}) in the V3 GS , the highest BFW was achieved with applications of poultry manure (25.08 g plant^{-1}) and vermicompost (23.05 g plant^{-1}) in the R1 GS (Table 3).

Table 3. The Effects of Organic Fertilizers (FA) on Biological Fresh Weight (BFW) and Biological Dry Weight (BDW) of Soybean at the V3 and R1 Growth Stage (GS).

		Biological Fresh Weight (g plant $^{-1}$)			Biological Dry Weight (g plant $^{-1}$)	
	V3	R1	Mean	V3	R1	Mean
Vermicompost	8.32^{d}	23.05^{ab}	15.68^{A}	1.23^{e}	3.42^{d}	2.32^{B}
Sheep manure	6.12^{d}	21.24^{b}	13.72^{A}	1.43^{e}	4.90^{b}	3.16^{A}
Cattle manure	5.39^{de}	13.95^{c}	9.67^{B}	1.26^{e}	3.28^{d}	2.27^{B}
Poultry manure	5.66^{de}	25.08^{a}	15.37^{A}	1.28^{e}	5.67^{a}	3.47^{A}
Control	2.70^{e}	12.13^{c}	7.42^{C}	0.92^{e}	4.15^{c}	2.53^{B}
Mean	5.66^{B}	19.09^{A}		1.22^{B}	4.28^{A}	
CV		12.63			11.10	
LSD	GS	1.921**			0.377**	
	FA	2.149**			0.421**	
	GS x FA	3.039**			0.596**	

The difference between the averages indicated by the same letter in the same group is not statistically significant. **: Significant difference at P<0.01 level, CV: Variation coefficient, LSD: Least Significant Difference

Table 4. The Effects of Organic Fertilizers (FA) on Root Fresh Weight (RFW) and Root Dry Weight (RDW) of Soybean at the V3 and R1 Growth Stage (GS).

		Root Fresh Weight (g plant $^{-1}$)			Root Dry Weight (g plant $^{-1}$)	
	V3	R1	Mean	V3	R1	Mean
Vermicompost	3.87^{cd}	7.90^{a}	5.88^{A}	0.76^{e}	1.58^{cd}	1.17^{B}
Sheep manure	2.49^{de}	7.61^{a}	5.05^{A}	0.91^{de}	2.52^{b}	1.72^{B}
Cattle manure	1.29^{e}	3.32^{cd}	2.30^{C}	0.77^{e}	1.98^{bc}	1.38^{B}
Poultry manure	1.45^{e}	6.07^{b}	3.76^{B}	0.85^{de}	3.99^{a}	2.42^{A}
Control	0.95^{e}	4.11^{c}	2.53^{C}	0.52^{e}	2.62^{bc}	1.39^{B}
Mean	2.01^{B}	5.80^{A}		0.76^{B}	2.47^{A}	
CV		19.57			23.62	
LSD	GS	0.941**			0.469**	
	FA	1.053**			0.525**	
	GS S x FA	1.489**			0.743 **	

The difference between the averages indicated by the same letter in the same group is not statistically significant. **: Significant difference at P<0.01 level, CV: Variation coefficient, LSD: Least Significant Difference

Among the organic fertilizers, the mean highest BDW was achieved with poultry manure (3.47 g plant^{-1}) and sheep manure applications (3.16 g plant^{-1}). The other organic fertilizers showed similar effects to the inorganic fertilizer application. While the mean lowest BDW was determined with inorganic fertilizer application (0.52 g plant^{-1}) in the V3 GS, with the highest for poultry manure (5.67 g plant^{-1}) and sheep manure (4.90 g plant^{-1}) applications in the R1 GS (Table 3).

Gul and Arslanoglu (2020) reported that highest biological yield was achieved with poultry manure (116.7 g plant^{-1}) and the lowest biological yield (97.9 g plant^{-1}) was produced with cattle manure and inorganic fertilizer. Similar results were reported by Khaim et al. (2013) for soybean. The poultry fertilizer had a positive effect on the growth and yield of soybean (Tagoe et al. 2008). Similar trend was also observed in other plants treated with poultry manure. For example, the highest maize yield was produced by poultry manure application at the rate of 7 t ha^{-1} (Soro et al. 2015) and in broccoli, the best results of yield and vegetative growth characteristics by 200 L ha^{-1} poultry manure application (Jigme et al. 2015). Also, the application of organic fertilizer significantly increased vegetable yield and quality due to the higher N mineralization resulting from higher biological activity (Li et al. 2017), and improved tea quality (Lin et al. 2019).

The highest BFW were for vermicompost, poultry manure and sheep manure, while the lowest BFW was in the inorganic fertilizer application. In the Table 1, it can be seen that the highest values were related to high OM content. In the aforementioned applications, the plants grew quickly in the presence of OM. So, BFW was highest for organic fertilizers because they increased the water retention capacity of the soil (Devi et al. 2013). In the R1 GS, the higher organic matter levels in the vermicompost and poultry manures may have contributed to the vegetative parts of the plants growing more quickly and the BWFs being higher. At the same time, it can be linked to phosphorus (P) effect; the P contents of these organic fertilizers are relatively much higher (> 2 times) than in the sheep and cattle manures (Tables 1 and 3). BDW is a better indicator of plants' dry matter accumulation and seed yield. In the present study, as like BFW, among the fertilizer applications, the highest BDWs were produced with poultry manure and sheep manure; for the interaction of GS with FA, the highest BDW was achieved with poultry manure in the R1 GS.

The growth stages (GS), fertilizer applications (FA) and their interaction (GS x FA) were significant ($p<0.01$) in terms of root fresh and dry weight (Table 4). The mean root fresh weight (RFW) was higher in the R1 GS (5.80 g plant^{-1}) than in the V3 GS (2.01 g plant^{-1}). Among the fertilizer applications, the vermicompost (5.88 g plant^{-1}) and sheep manure (5.05 g plant^{-1}) applications most increased the RFW, followed by poultry manure application (3.76 g plant-1). The cattle manure and inorganic fertilizer applications were decreased the RFW. For interaction between GS to FA, the highest RFWs were achieved with the vermicompost and sheep manure applications at 7.90 g plant^{-1} and 7.61 g plant^{-1}, respectively, in the R1 GS, and the lowest RFW was found for the cattle manure and inorganic fertilizer applications (Table 4).

Among the fertilizer applications, the highest root dry weight (RDW) was achieved with poultry manure application (2.42 g plant^{-1}), but all of the other fertilizer applications were given same results. In the V3 GS, the fertilizer applications were similar too, the highest RDW (3.99 g plant^{-1}) was measured for poultry manure in the R1 GS (Table 4). Vermicompost and sheep manure applications increased RFW; but, the highest RDW resulted from poultry manure application. Results of the present study also showed that increasing OM content and N increased growth; but optimal P and Kpercentages were also important for dry matter accumulation in the plant. As can be seen in Table 1, poultry manure had higher P (2.2 %) contents than the other organic fertilizers which was reflected in higher BDW and RDW levels (Tables 1-3-4). The total N concentrations in poultry and sheep manure (3.2 % and 2.1 %, respectively) and K (potassium) (1.7 % and 0.9 %, respectively) were higher than in the other OFs (Table 1). These results may indicate that especially P and K affect the rate of dry matter accumulation. Kuntyastuti et al. (2018) reported that among organic fertilizer treatments, (namely 2.5 t cow manure ha-1, 5 t cow manure ha-1 and 2 t Santap NM-2 ha-1), there were no significant differences in mean root and plant dry weight (BDW) 40 days after planting. In the present study, the values obtained in the V3 GS (44 days after planting) were similar to those reported by Kuntyastuti et al. (2018). However, as the plant growth progressed, dry matter accumulation in the roots and plants increased (Miladinovic and Dordevic 2011), with significant differences in the R1 stage for both variables in our study.

The researchers have recommended manures of cattle, sheep and poultry (Carvalho et al. 2011), vermicompost and manure fertilizers as yield increasing and environmentally friendly fertilizers (Zerihun and Haile 2017; Martey 2018), profitable (Mamia et al. 2018). Poultry manure is one of the best manures because it contains a relatively high N content and available P (Baghdadi et al. 2018). Soybean fertilization with poultry litter increased shoot dry matter, root dry matter. For this reason, it can replace inorganic fertilizers in terms of achieving soybean growth (Ragagnin et al. 2013) or at least reduce the input of inorganic fertilizers (Passos et al. 2014).

Abbas et al. (2011) reported that 48 m3 ha-1 FYM application could replace inorganic fertilizer while Gul and Arslanoglu (2020) reported that poultry manure could be used instead of inorganic fertilizers for soybean farming. Gautam and Pathak (2014) stated that there was a significant association between plant biomass and the seed yield of soybean. In addition, Gai et al. (2017) reported that the highest seed yield in soybean was associated with fertilizer applications that produced the highest RDW.

Based on this information, although poultry manure application produced the lowest number of nodules but, seed yield could be expected to be high in harvest due to high BDW and RDW, as stated by Tagoe et al. (2008). Furthermore, would the high seed yield from vermicompost application? Which resulted in high values for all the criteria examined, except for root and BDW? In addition, would high yield be achieved with well-developed root and plant systems? To answer these questions, further studies should be conducted with the organic fertilizers used in the present study to determine how they affect root and plant growth in the later GSs of soybean.

4. Conclusions

Vermicompost created the best environment for growth, which was evidenced by the highest increase in plant height, root length, BFW, RFW and the number of nodules by promoting faster growth and development, while it reduced the BDW and RDW. Inorganic fertilizer application was the lowest in terms of all characteristics examined except root length. Thus, our hypothesis was strongly validated only in terms of vermicompost and poultry manure application. Although the plants' good development root and shoot suggests that dry matter accumulation would also increase, this effect was not seen in RDW and BDW in vermicompost application. Poultry manure application, which is richer in terms of OM and total nitrogen, total phosphorus and potassium, was found to be effective regarding RDW and BDW. Vermicompost and poultry manure applications are likely to produce stronger root and plant growth in soybean farming and are a possible alternative to inorganic fertilizer application, although finding the huge quantities needed for large scale farming may prove difficult.

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