OPTIMIZATION AND COMPARISON OF THE EFFECTS OF VERMICOMPOST AND CONVENTIONAL FERTILIZATION ON SPINACH (*SPINACIA OLERACEA* L.) GROWTH

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Abstract. Vermicompost helps soil to retain water, regulate soil temperature and structure, and helps solve the soil's nutrient problem. The aim of our study was to compare chemical fertilization with different rates of vermicompost treatments in terms of growth properties, yield, and nutrient element content of spinach (*Spinacia oleracea* L.). We also determined the appropriate rate of vermicompost application for spinach. The experiment was repeated in two successive seasons with five treatments in the experiment: (1) control, (2) 1 ton vermicompost/ha, (3) 2 tons vermicompost/ha, (4) 3 tons vermicompost/ha, and (5) chemical fertilization. To assess the effect of the treatments in spinach, soil analysis (soil texture, pH, EC (Electrical Conductivity), percent of calcium carbonate, organic matter, and macro and micro elements), plant height and yield of spinach plants, and plant nutrient element analysis of spinach leaves were performed. Evaluation of the results indicated that vermicompost had positive impacts on the soil and the plant; the best treatment rate was 3 t/ha. This vermicompost application rate resulted in a 149% yield increase compared with the chemical fertilizer treatment.
Keywords: *earthworm, vermicompost, Spinacia oleracea, organic fertilizers, yield, nutrient elements content*

Introduction

The main objective of agricultural production is to provide food enough to meet requirements of population in good quality that will not harm health of human beings. For this purpose, it requires the development and application of new inputs and technologies. New agricultural technologies, including agrochemicals (fertilizers, pesticides, etc.) and intercropping, are being randomly used to improve the success of modern agriculture. Some of these technologies are causing our soils to become ill, environmental pollution, increased pest resistance in weeds, insects, and pathogens, and toxic residue in our food (Narwal, 2010). Fertilizing and irrigation are the main inputs in agricultural production. Prior to any kind of agricultural production, artificial fertilizer is applied to eliminate nutritional deficiencies in the soil. For an effective fertilizing process, improving the availability of the nutrients supplied by fertilizers is equally significant as the fertilizer treatment. Nowadays, human and public health and environmental protection is becoming more important and in this case, using of organic manure is getting higher. Organic matter has a fairly high importance on soil productivity and soil serves several functions. For this reason, farmers preserve resources to minimize the artificial inputs from outside the farm, and manage pests (weeds, insects, nematodes, and pathogens) via internal regulating mechanisms based on ecological principles and processes (Stinner and House, 1987). Organic agriculture is often proposed as a solution for producing food with reduced environmental impact

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(Tilman, 1998; Scialabba and Hattam, 2002). Even though it constitutes less than 1% of global agricultural land and less than 5% of retail sales in most high-income countries (Willer and Lernoud, 2015), it represents one of the fastest growing food sectors (Seufert et al., 2017).

Vermicompost, the excreta of the earthworm, can improve the health and nutrients of the soil. Vermicompost helps manage waste as a valuable compost and biocontrol agent. In soil quality improvement, using vermicompost waste is better compared to traditional compost and landfill (Joshi et al., 2015). Vermicompost helps with soil water retention, regulation of soil temperature and structure, enhances the soil with nutrient elements, and increases the biomass and community structure of the microbial population (Vivas et al., 2009).

Vermicomposting consists of a simple biotechnological composting process. Here, certain earthworms were used to improve the waste conversion process to yield a better product. This mesophilic process used microorganisms and earthworms that are active between 10 and 32 °C, which are not ambient values; however, these are the values in moist organic material. This process is faster than composting. The reason for this is that the material passes through the earthworm's gut, then a transformation occurs that results with earthworm's castings (worm manure) that are rich in microbial activity and plant growth regulators and fortified with pest repellence attributes. Briefly, earthworms can transform garbage into "gold" (Gandhi et al., 1997; Julka, 2001). Vermicompost has 1.5–2.2% nitrogen (N), 1.8–2.2% phosphorus (P), and 1.0–1.5% potassium (K) on average. The organic carbon content is between 9.15 and 17.98%, and has micronutrients such as sodium (Na), calcium (Ca), zinc (Zn), sulphur (S), magnesium (Mg), and iron (Fe) (Adhikary, 2012).

Spinach (*Spinacia oleracea* L.) is a significant source of organominerals, such as vitamin B complex, ascorbic acid, vitamin A, and carotin (Bhattacharjee et al., 1998). Spinach is used in a variety of meals, such salad and with cooked meat and vegetable dishes (Molerock and Correll, 2008). Spinach best grows in cool climates, in an optimum temperature range of 7 and 24 °C. The minimum temperature for spinach seed germination is 2 °C (Molerock and Correll, 2008).

Crop yield quality and size are mostly affected by fertilization (Jablonska-Ceglarek and Rosa, 2001), so fertilizers with different mineral constituents create differences in the yield and nutritional quality of the crop. Nitrogen is the nutrient that most strongly affects nutritional quality differences in crops. Simultaneously treatment with organic and inorganic fertilizer has been found to be the most effective at improving crop production (Chaoui et al., 2003). Organic foods are often seen as healthier and more nutritious and better in quality compared with conventionally grown foods (Kansal et al., 1981).

Due to its short vegetation period and high market demand during winter, the amount of spinach production increases each year. Spinach is a vegetable whose leaves are eaten, thus the treatment of fertilizers and pesticides used during its growth requires special attention. This study was performed to determine the impacts of different rates of vermicompost application on soil properties, yield, and some growth properties and nutrient element contents in the leaves of spinach. Also, vermicompost treatments with and without artificial fertilizers were compared in terms of the properties mentioned above. We believe that this is a healthy and environment-friendly production technique for both the soil and crop, and especially in leafy vegetables such as spinach.

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Materials and methods

Experiment location

The experiment was performed at the research station belonging to Turgut Ozal University, Agriculture Faculty, Department of Horticulture, Battalgazi, Malatya, Turkey (38°25’22” N and 38°21’30” E) in two consecutive years: spring (from March to May) and fall (from October to April) 2015. The study area is located 790 m above the sea level. The soil of the study area has an A-Bw–C1-C2 horizon with a soil temperature typical of mesic soil, an acidic moisture regime, and is classified as Aridisol Ordo, Orthid sub Ordo, and Camborthid big group. The soils in the experimental area were clean with no pesticide residues as no planting had occurred in the experimental area for a long time. For the second growing period in the experiment, a location that was not cultivated in the first year was used. Soil analyses were performed both prior to seed sowing (no treatment) and also after harvesting for V300 (3 tons vermicompost/ha) treatment in the first (spring) season.

Plant material

As plant material, the Sprinter F_1 spinach cultivar with high market quality, flat leaf surface, wide oval shape, bright green color, bump foliar, medium stem with high yield potential, and fast growth was used in the experiment (*Fig. 1*).

Figure 1. *Sprinter F_1 is spinach cultivar that used in the experiment*

Experimental layout

In spring 2015, two months elapsed from sowing the spinach seeds to the harvest time; the time elapsed in fall was around six months. In this study, the experiment was repeated in two successive seasons: the first experiment covered the spring season from March 19 to May 14, 2015, for a total of 56 days, and the second experiment covered the autumn-winter-early spring seasons from October 8, 2015 to April 17, 2016, for a total of 192 days. The Malatya climate data during the spinach growing season in the field are provided in *Table 1*.

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Table 1. *Average climate data in Malatya, Turkey during the 2015 and 2016 growing season*

	October	November	December	January	February	March	April	May	June
Average temperature (°C)	15.4	7.8	2.0	−0.4	1.4	6.7	13.0	18.1	23.2
Average highest temperature (°C)	21.3	12.5	5.4	3.1	5.3	11.5	18.3	23.9	29.5
Average lowest temperature (°C)	9.8	3.9	−0.9	−3.4	−2.2	2.1	7.5	11.9	16.1
Average sun bathing time (hour)	7.3	5.2	3.1	3.2	4.2	5.4	7.2	9.2	11.4
Average rainy days	6.7	8.6	10.8	10.9	10.7	11.0	10.7	10.0	4.7
Monthly total rainfall amount (mm)	35.9	42.0	39.9	42.1	40.7	48.9	54.7	44.5	17.1

Experimental design

The experiment had a random block design with five treatments and three replications. For each replication, treatment size was 5 × 5 m = 25 m^2 and the total area used in the experiment excluding edge effects was 375 m^2. Since the experimental area is small, spinach seeds were planted by spreading, and the space between the rows and over rows was 30 cm and 2–3 cm, respectively, by rarefying the plants after emergence. Seeding density was 375 g seed in each area (10 kg per ha).

Fertilizer treatments in the experiment were as follows: (1) control without fertilizer (WF), (2) 1 ton (1000 kg) vermicompost/ha (V100), (3) 2 tons (2000 kg) vermicompost/ha (V200), (4) 3 tons (3000 kg) vermicompost/ha (V300), and (5) chemical fertilization (CF). The CF treatment included a mixture of pure N 1 kg/ha, 1 kg/ha phosphorus (P_2O_5), and 1.2 kg/ha potassium (K_2O), by calculating chemical fertilizers (Şalk et al., 2008). Vermicompost was produced in our faculty and is not commercial. After the production, pre-experiments were carried out to determine the dose in pepper, tomatoes, lettuce and spinach growing. In the results of spinach; we were not found significant difference between 3 tons of vermicompost treatment per hectare and 4 tons of vermicompost treatment per hectare in terms of plant growth and yield. For this reason, we preferred 3 tons of vermicompost/ha dose at the highest level in vermicompost treatments in this study.

In the spring growing period (Experiment 1), fertilizer treatments were applied into the soil two days prior to sowing as base fertilizer. In the fall growing period (Experiment 2), fertilization was performed in two parts: the first treatment was two days before sowing and the second treatment occurred during the first week of March after the cold winter days. Vermicompost was applied in solid form at the same time as chemical fertilization. In spring, all treatments were applied before sowing once as base fertilizer and in the fall season, it was split into parts: half prior to planting and the rest in the first week of March.

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Vermicompost preparation

In the experiment, solid vermicompost produced at Turgut Ozal University was used. Vermicompost was produced by *Eisenia foetida* worms called Red California worms. We also used farm manure. We placed the worms inside the farm manure. Vermicomposting is a mesophilic process where the farm manure passes through the earthworm gut, and changes the physical and chemical structures of the farm manure occurs through this process, which results in earthworm castings (worm manure). The worm gut activity is similar to a small composting tube that mixes conditions and inoculates residues (Abbot and Parker, 1981). A synergistic relationship exists between moisture, pH, and microbial populations in the gut, creating an excellent byproduct appears (Becker, 1991). Every day, worms swallow large soil amounts that have organic substances (germs, plants, and animal debris). They then grind these in their gizzard and digest them in intestine with the help of enzymes (Scheu, 1987). Then, solid forms of vermicompost were applied to the spinach-growing soil. The properties of vermicompost used in the experiment are outlined in *Table 2*.

Table 2. *Some selected physical and chemical properties of the vermicompost used in the experiment (Durak et al., 2017)*

Property	Value
pH	8.89
$CaCO_3$	11.30%
Organic matter	55%
EC	0.009 mmhos /cm
Total nitrogen	2.55%
P (combustion)	9376.46 ppm
P (Olsen method-plant available phosphorous)	2193 ppm
K (Dry combustion method)	11263.10 ppm
K (Soluble in ammonium acetate)	4635 ppm
Ca (Combustion method)	24366.60 ppm
Ca (Soluble in ammonium acetate)	2072.25 ppm
Mg (Dry combustion)	4894.80 ppm
Fe (Dry combustion)	3797.45 ppm
Mn (Dry combustion)	275.08 ppm
Zn (Dry combustion)	94.95 ppm

Soil analyses

Soil analyses were performed both prior to planting and after harvesting. Soil texture analyses was performed according to the Bouyoucos hydrometer method (Gee and Bauder, 1986). pH and electrical conductivity (EC) were measured in soil water solution (1:2.5) using a pH meter with glass electrode and EC meter, respectively (Richards, 1954). Calcium carbonate ($CaCO_3$) (%) was measured using a Scheibler Calcimeter (Allison and Moodie, 1965). Soil organic matter was measured according to the modified Walkley-Black method with the soil available in terms of phosphorous (mg kg^{-1}) by measuring P in the extracts after $NaHCO_3$ extraction using a spectrometer (Olsen and Dean, 1965). Extractable potassium (mg 100 g^{-1}) was determined in a flame

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photometer in the extracts obtained after soils were shaken and centrifuged with 1 N (Normality) ammonium acetate three times (Knudsen et al., 1982). Total and extractable Fe, Zn, Cu, and Mn (mg kg^{-1}) in the extracts were determined by shaking soil HNO_3 and HCI mixtures (Baker and Amacher, 1982) and diethylenetriaminepentaacetic acid (DTPA) solution using an Atomic Adsorption Spectrometer and filtered using Whatman 42 filter paper (Lindsay and Norvell, 1978).

Plant analyses and measurements

Plant heights of 10 randomly selected plants from each replicate were measured and averaged. The roots of the spinach were separated from the aboveground biomass when determining fresh matter yield. For yield measurements, plants at harvesting time were harvested with their roots and weighed after roots were washed and separated from the aboveground biomass. The final yields were obtained as kg m^{-2}. For the analyses of the nutrients in plant leaves, 10 mature leaves were randomly selected from each replication and were first washed with tap water, later with pure water, and left for air drying. Dried leaves were grinded in a mill and prepared for analyses (Kacar, 1995; Kacar and Inal, 2008).

For nitrogen analyses, a modified Kjeldahl method was used (Kacar, 1995; Kacar and Inal, 2008). Phosphorous, in dried and grinded plant samples, was measured in the extracts prepared according to dry combustion. P in the extracts was determined with the Vanado Molibdo Phosphoric Yellow Color method using a spectrophotometer. For measurement of K content, a flame photometer was used to measure K in the extracts obtained by extracting the plants burned in ash furnace using 3 N HCI as previously described (Plank, 1992). Fe, Mn, Mg, and Zn contents in the plant were determined using an Atomic Adsorption Spectrometer after the plants were burnt according to the dry combustion method (Kacar, 1995; Kacar and Inal, 2008; Karaman et al., 2012).

Data analyses

Experiments were performed over two successive seasons according to a randomized block design with three replications. The data obtained each season were subjected to analysis of variance (ANOVA) using the SPSS statistical program (SPSS version 20). The data were subjected to factorial analysis of variance, and means were separated by a Duncan's Post Hoc Test with a 5% level of significance ($p < 0.05$).

There were no significant interactions and differences between two growing season; therefore, the data belongs to Experiment 1 and Experiment 2 were pooled. Accordingly, the results have not presented separately.

Results

The results of both soil and also plant analyses in two successive growing seasons (spring and fall growing period) were very close to each other. For this reason, the results presented in the study were obtained by averaging the values of both.

Soil analyses results

The results of soil analyses performed both prior to sowing (no treatment) and after harvesting in V300 treatment area (3 tons/ha) are presented in *Table 3*.

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Table 3. *Some physical and chemical properties of experimental area soils prior to planting (no treatment) and after harvesting (in V300 treatment) in the spring season*

Season	Texture	pH	Salt (mmhos/cm)	CaCO3 (%)	Soil organic matter (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
BS	Clay loam	7.49 ±0.21	0.005 ±0.001	39.9 ±0.2	1.92 ±0.12	9.00 ±0.91	526.15 ±12.12	4038.46 ±29.31	689.18 ±24.22	0.59 ±0.09	6.42 ±0.71	0.58 ±0.11	2.55 ±0.45
AH	Clay loam	7.45 ±0.23	0.006 ±0.001	39.9 ±0.3	1.97 ±0.13	7.58 ±0.77	497.73 ±10.09	4200.00 ±37.14	765.53 ±34.53	0.63 ±0.09	21.9 ±1.14	0.68 ±0.09	2.85 ±0.24

BS: Before sowing (no treatment); AH: After harvesting

Differences in the results of the analyses performed in soil samples obtained before planting and after harvesting were observed and pH decreased within the short growing period. Similarly, a decline was observed in salt content. Due to plant uptake, potassium and phosphorous contents of the soils decreased whereas organic matter levels increased (*Table 3*).

Plant height and yield production of spinach

We observed that spinach height and yield were better in the vermicompost treatments compared with both the control and chemical fertilizer treatments (*Figs. 2* and *3*). Total spinach yield was statistically different at a $p < 0.01$ significance level in V200 and V300 vermicompost treatments compared with the control (*Fig. 3*). According to the evaluation of plant heights, V300 treatment was found statistically different at the $p < 0.05$ significance level (*Fig. 2*). V300 treatment had higher values recorded than other treatments.

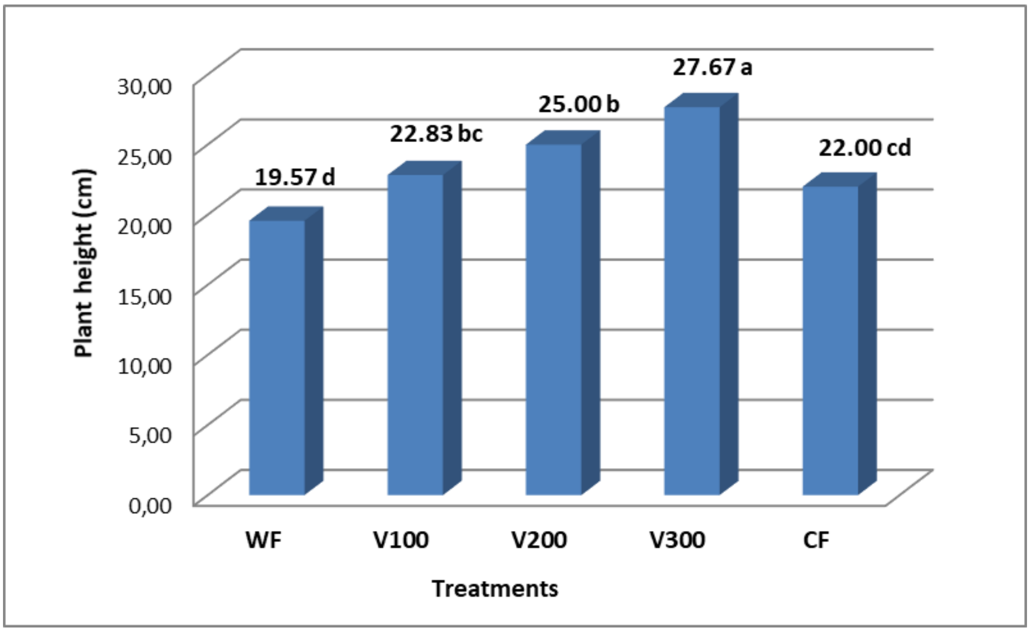

Figure 2. *Average plant heights of the control treated with chemical fertilizer and vermicompost at different application rates. The means followed by different letters are significantly different (p < 0.05). WF: control without fertilizer, V100: 1 ton vermicompost/ha, V200: 2 tons vermicompost/ha, V300: 3 tons vermicompost/ha, and CF: chemical fertilizer*

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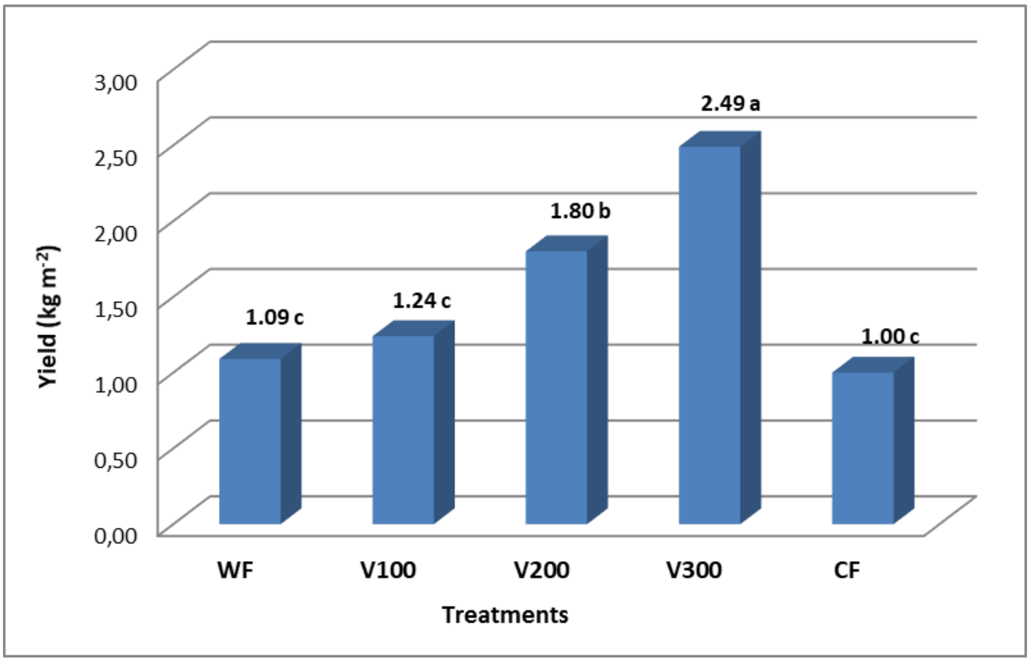

Figure 3. *Crop yields of vermicompost and chemical fertilizer at different rates and control areas. The means followed by different letters are significantly different (p < 0.01). WF: control without fertilizer, V100: 1 ton vermicompost/ha, V200: 2 tons vermicompost/ha, V300: 3 tons vermicompost/ha, and CF: chemical fertilizer*

The highest yield was obtained with the V300 treatment followed by the V200 treatment. The yields obtained with V100, CF, and WF treatments were closer to each other, and therefore, they were grouped together (*Fig. 3*).

Nutrient contents of plant leaves

As seen in *Table 4*, all nutrients except Fe were within the adequate limits for spinach. The main reasons for the high Fe content were that the experimental area had not been used for agriculture for a long time, and the higher Fe uptakes from vermicompost. In terms of N content, no difference was observed among the treatments. The lowest nitrogen content was recorded in the controls with no fertilizer treatment. In statistical evaluation, the V100 treatment was grouped with the treatment with no fertilizer. The highest nitrogen content was determined in the chemical fertilizer treatment areas, followed by the V300 then V200 treatments.

P content ranged between 0.23 and 0.36%. The lowest P content was recorded in the treatments with no fertilizer, whereas the values in other treatments were found close to each other. There were no statistically significant differences among treatments.

The K content of the leaves ranged between 2.12 and 6.03%. These differences were found to be statistically significant. The lowest K content was found in the treatments with no fertilizer, whereas the highest values were determined in the treatments where only chemical fertilizers were applied. V100 treatment was grouped with the WF treatment. V200 and V300 treatments were also grouped together.

Ca content of different fertilizer treatments were not found to be statistically significant and they ranged between 0.68 and 0.81% in the study.

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Table 4. *Average nutrient contents of plant leaves treated with Vermicompost, chemical fertilizer at different doses and the controls*

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
WF	2.76 c	0.23	2.12 b	0.68	0.49 b	201.3 c	42.5	23.9	5.6
V100	3.28 c	0.32	3.21 b	0.80	0.57 ab	434.9 b	48.9	40.2	5.8
V200	4.01 b	0.36	4.77 ab	0.78	0.75 a	561.5 a	64.5	45.6	6.9
V300	4.86 ab	0.36	4.97 ab	0.81	0.79 a	534.3 a	68.2	53.8	7.3
CF	4.93 a	0.32	6.03 a	0.76	0.65 a	496.4 a	58.7	44.4	7.5
Adequate range for spinach	4.0–6.0	0.3–0.6	5.0–8.0	0.7–1.2	0.6–1.0	60–200	30–250	25–100	5–25

The means in the columns followed by different letters are significantly different ($p < 0.05$). WF: control without fertilizer, V100: 1 ton vermicompost/ha, V200: 2 tons vermicompost/ha, V300: 3 tons vermicompost/ha, and CF: chemical fertilizer

According to nutrient analyses results of the leaves, the Mg content of the leaves differed among fertilizer treatments and these differences were statistically significant. The highest Mg content (0.79%) was found in V300 treatment, followed by V200 and CF (0.75–0.65%), and these three treatments were grouped together. The lowest Mg content (0.49%) was determined in the WF treatment, whereas the V100 treatment with 0.57% was the intermediate group.

The evaluation of the results of the micronutrients in spinach leaves showed that the V300 and V200 treatments provided better results than other treatments. Among the micronutrients, the Fe content impacted the micronutrients significantly ($p < 0.05$) in the treatments. Fe content was the highest in the V200, V300, and CF treatments followed by the V100 treatment, whereas the lowest values were recorded in the WF treatment. In the spinach leaves, the Mn levels ranged between 42.5 and 68.2 ppm, Zn content from 23.9 to 53.8 ppm, and Cu content from 5.6 to 7.5 ppm, depending on different treatments. Differences in the contents of the Mn, Zn, and Cu were not found to be statistically significant ($p < 0.05$).

Discussion

Vermicompost treatment enhanced the quality parameters of the soil in this study. Castings slow-released nutrients that were ready for the plants. Castings include plant nutrients, which dissolve slowly instead of immediate nutrient leaching, as they are encased in a mucus membrane secreted by the worms. The product has excellent soil structure, porosity, aeration, and water retention capabilities, which may insulate plant roots against extreme temperature values, decrease erosion, and control weeds (Suhane, 2007). According to the results of the soil analysis in our study, the pH was reduced in the soil and the organic matter was increased by vermicompost application. Spinach plants had uptake potassium and phosphorus more with vermicompost treatments, so the amount of phosphorus and potassium in the soil was decreased.

Red worm castings have high humus content, which causes soil particles to be converted into clusters to form a channel for air by improving the capacity to retain water. When there are worms, the compacted soil is regenerated and the water

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penetration is enhanced at a rate of more than 50% (Ghabbour, 1973; Capowiez et al., 2009). In this study, vermicompost has provided nutrients to be better uptake by the spinach plant by increasing the proportion of humus in the soil. The humic acid in humus forms binding sites for plant nutrients like calcium, iron, potassium, sulfur, and phosphorus. Humic acid also enhances the plant growth although at a slower rate (Canellas et al., 2002), and is essential for plants from three aspects: (1) enabling the plant to extract nutrients from soil, (2) helping the plant to dissolve minerals that were not dissolved for delivering organic matter to plants for use, and (3) stimulating root growth. Even the chemical fertilizers are more effective when humus is present in the soil (Li and Li, 2010). Bacteria, enzymes, and remnants of plant materials not digested by worms exist in worm castings, which are actually biologically active mounds. The microbial activities of useful microorganisms in the castings are considerable, with rates 1–20 times greater than in normal soil (Edwards, 1995). Nitrogen-fixing and phosphate solubilizing bacteria, known as the actinomycetes and mycorrhizal fungi, are among useful soil microorganisms stimulated by earth worms (Scheu, 1987). Castings also slow-release nutrients ready for plants and include plant nutrients encased in mucus membranes (Edwards, 1995).

In this study, macro and micro nutrient contents of spinach leaves were found to be higher in vermicompost treatments than WF and CF treatments. The micro and macro nutrient contents of spinach in the areas treated with vermicompost were always higher compared with those treated with mineral components, which can be explained by the release and availability of the micronutrients after mineralization of organic materials. Additionally, microorganisms in the rhizosphere area provided by vermicompost treatment increased the availability of nutrients, such as N and K, by improving nitrogen fixation and biological solubilization of P (Mackey et al., 1982). Fe content was determined high when compared with reference values for spinach, which may be attributed to the fact that no agricultural activity had been performed in the study area.

According to the results of previous studies, vermicompost treatments were increased nutrient element contents in the leaves of plants. Pant et al. (2009) reported relatively higher micro nutrient (B, Zn, Fe, Mn, and Cu) content in the tissues of pak choi (*Brassica rapa*) in the areas treated with non-treated vermicompost tea than those treated with aerated vermicompost tea and vermicompost tea combined with microbial enhancer and controls. Vermicompost treatment increased nutrient content in different parts of other plants, such as N, P, K, Zn, Fe, Mn, and Cu content in geranium (*Pelargonium* species); average N, P, K, and Mg content of plant tissue of *Amaranthus* species; and N, P, K, and Ca content of groundnut (*Arachis hypogaea*) and marigold (*Tagetes*) plant; K, Zn, Ca, and Fe content in the stem and root tissues of Lilium plant; K and Ca content of marigold (*Tagetes*) plants; total N (%) of spinach; and P content in the leaves of maize (*Zea mays*) (Peyvast et al., 2007; Uma and Malathi, 2009; Shadanpour et al., 2011; Chand et al., 2011; Mycin et al., 2010; Gutie'rrez-Miceli et al., 2008; Moghadam et al., 2012). Uptake of P and K by African marigold (*Tagetes*) and uptake of K, Ca, and Mg by Setaria grass plants increased with vermicompost treatment (Jaworska and Kmiecik, 1999; Mackey et al., 1982). Increases in uptake and availability of nutrients were explained by improved soil environment and humic acid released after vermicompost treatment (Mycin et al., 2010; Stevenson, 1991; Nardi et al., 2002).

In our study, the reason for the improvement of soil properties and increase of nutrient element contents in the spinach leaves due to vermicompost treatments; it can be said that the increase of soil humus and microbial activity in vermicompost

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applications is the result of decrease of pH value. Hence, the plant height and yield of the plants in the vermicompost treatments were found to be higher than control and chemical treatments.

According to the results of this study, with the highest plant height values obtained in V300 treatment in mind, the treatments of V200, V100, CF, and WF followed these values, in decreasing order. The plant height results for V300 treatment were determined to be 29% higher than WF treatment and 20% higher than CF treatment.

In similar study results, vermicompost treatments were found to increase plant height. Peyvast et al. (2008) investigated the effect of four different application rates (0, 10, 20, and 30%) of vermicompost obtained from cattle dung on spinach (*Spinacia oleracea*) under greenhouse conditions. The highest and the lowest plant heights in spinach were obtained with the 10% and 0% vermicompost treatments, respectively, and the plant heights of 14.30 and 14.16 cm were obtained with 20% and 30% vermicompost treatments, respectively. Although the treatments of all three vermicompost rates compared to the control increased the plant heights, these increases were not statistically significant. In potato (*Solanum tuberosum*), the highest plant height was obtained through incorporating a mixture of vermicompost and 100% NPKS (chemical fertilizers) into soil (Alam et al., 2007). Taller plants in *Abelmoschus esculentus* were obtained with vermicompost prepared from *perithecium* compared to control (only soil) and soil treated with the recommended dose of chemical fertilizers (Vijaya et al., 2008). Crossandra (*Crossandra undulaefolia*) had higher plant heights when it was grown in pots treated with water and hyacinth vermicompost compared to when grown in the control pots and in pots treated with water hyacinth compost (Gajalakshmi and Abbasi, 2002). A six t/ha vermicompost treatment improved the plant height of eggplant (*Solanum melongena*) compared to control without vermicompost (Moraditochaee et al., 2011).

In some of the previous studies, the growth responses of plants in vermicompost was claimed to resemble hormone-induced activity, which is related to high nutrient levels, humic acid, and humate in vermicompost (Edwards and Burrows, 1988; Atiyeh et al., 2000a). A positive vermicompost effect includes stimulated seed germination in some plants like green gram (Karmegam et al., 1999), tomato (Atiyeh, 2000b; Zaller, 2007), petunia (Arancon et al., 2008), and pine trees (Lazcano et al., 2010). Also, vermicompost enhances vegetative growth by stimulating shoot and root development (Edwards et al., 2004) and the morphology of the seedling by increasing leaf area and root branching (Lazcano et al., 2009) Vermicompost has been demonstrated to stimulate plant flowering and increase the number and biomass of flowers (Arancon et al., 2008; Atiyeh et al., 2002) and increase fruit yield (Singh et al., 2008; Atiyeh et al., 2000b; Arancon et al., 2004a, b).

According to the results of this study, the highest yield was obtained in V300 treatment. The V300 treatment was followed by V200, V100, WF and CF respectively. The yield results for V300 treatment were determined to be 56% higher than WF treatment and 60% higher than CF treatment.

In previous similar studies, yield was determined higher in vermicompost treatments. Earlier research reported that vermicompost treatment increased the total yield of potato (Alam et al., 2007), two cultivars (Sultan and Storm) of cucumber (*Cucumis sativus*) (Azarmi et al., 2009; Singh et al., 2008), strawberry (*Fragaria X ananassa*) (Singh et al., 2008), *Abelmoschus esculentus* (Vijaya and Seethalakshmi, 2011), lettuce (*Lactuca sativa*) (Papathanasiou et al., 2012), and *Amaranthus* species (Uma and Malathi, 2009),

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the fruit yield of eggplant (*Solanum melongena*) (Alam et al., 2007), in marketable yields of tomato (*Lycopersicum esculentum*) (Uma and Malathi, 2009), fruits of okra (*Abelmoschus esculentus*) (Ansari and Sukhraj, 2010), and increased the harvest index of crossandra (*C. undulaefolia*) (Gajalakshmi and Abbasi, 2002). In addition, vermicompost treatments improved the oil yields of geranium (*Pelargonium* species) (Chand et al., 2011) and *Matricaria chamomilla* (Hadi et al., 2011).

Conclusions

Ecological agriculture, which is synonymous with sustainable agriculture, improves the fertility of the soil and creates a secondary income source for farmers, while focusing on total food protection and on the farm–human ecosystem. Vermicompost has potential to be applied in ecological agriculture systems. We believe that plant growth, yield and soil properties are enhanced by the application of vermicompost given our study results. In this respect, vermicompost could be applied in the near future as an alternative agriculture supplement combined with inorganic fertilizers. Spinach (*Spinacia oleracea* L.) is a unique crop as a vegetable with a relatively short growing period with high yield potential. In the present study, vermicompost positively impacted spinach yield and other plant parameters, as well as soil organic matter, as supported by the results of soil analyses, and plant analyses and measurements. Evaluation of the results indicated that vermicompost had positive impacts on the soil and the plant. The best treatment application rate was 3 tons vermicompost/ha. The study results suggest that the use of vermicompost for commonly consumed vegetables would increase the parameters and future experiments should be conducted for other vegetable species.

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REFERENCES

[1] Abbot, I., Parker, C. A. (1981): Interactions between earthworms and their soil environments. – Soil Biol. Biochem. 13: 191-197.

[2] Adhikary, S. (2012): Vermicompost, the story of organic gold: A review. – Agric. Sci. 3: 905.

[3] Alam, M. N., Jahan, M. S., Ali, M. K. Ashraf, M. A. Islam, M. K. (2007): Effect of vermicompost and chemical fertilizers on growth, yield and yield components of potato in Barind soils of Bangladesh. – J. Appl. Sci. Res.3: 1879-1888.

[4] Allison, L. E., Moodie, C. D. (1965): Carbonate. – In: Black, C. A. (ed.) Methods of Soil Analysis. American Society of Agronomy, Madison, WI, USA.

[5] Ansari, A. A., Sukhraj, K. (2010): Effect of vermiwash and vermicompost on soil parameters and productivity of okra (*Abelmoschus esculentus*) in Guyana. – Afr. J. Agric. Res. 5: 1794-1798.

[6] Arancon, N. Q., Edwards, C. A., Atiyeh, R. (2004a): Effects of vermicomposts produced from food waste on the growth and yields of greenhouse peppers. – Bioresour. Technol. 93: 139-144.

[7] Arancon, N. Q., Edwards, C. A., Bierman, P. (2004b): Influences of vermicomposts on field strawberries: Effects on growth and yields. – Bioresour. Technol. 93: 145-153.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_70017016

[8] Arancon, N. Q., Edwards, C. A., Babenko, A., Cannon, J., Galvis, P., Metzger, J. D. (2008): Influences of vermicomposts, produced by earthworms and microorganisms from cattle manure, food waste and paper waste, on the germination, growth and flowering of petunias in the greenhouse. – Appl. Soil Ecol. 39: 91-99. DOI: 10.1016/j.apsoil. 2007.11.010.
[9] Atiyeh, R. M., Subler, S., Edwards, C. A., Bachman, G., Metzger, J. D., Shuster, W. (2000a): Effects of Vermi-composts and Composts on Plant Growth in Horticultural Container Media and Soil. – Pedobiologia 44: 579-590.
[10] Atiyeh, R. M., Arancon, N. Q., Edwards, C. A., Metzger, J. D. (2000b): Influence of earthworm-processed pig manure on the growth and yield of green house tomatoes. – Bioresour. Technol. 75: 175-180.
[11] Atiyeh, R. M., Arancon, N., Edwards, C. A., Metzger, J. D. (2002): The influence of earthworm-processed pig manure on the growth and productivity of marigolds. – Bioresour. Technol. 81: 103-108. DOI: 10.1016/S0960-8524(01)00122-5.
[12] Azarmi, R., Giglou, M. T., Hajieghrari, B. (2009): The effect of sheep-manure vermicompost on quantitative and qualitative properties of cucumber (*Cucumis sativus* L.) grown in the greenhouse. – Afr. J. Biotechnol. 8: 19.
[13] Baker, D. E., Amacher, M. C. (1982): Nickel, Copper, Zinc, and Cadmium. – In: Page, A. L., Miller, R. H., Keeney, D. R. (eds.) Methods of Soil Analysis (2nd ed.) ASA, SSSA, Madison, WI, USA.
[14] Becker, B. (1991): The Benefits of Earthworms. – Nat. Food Farm.12.
[15] Bhattacharjee, S., Dasgupta, P., Paul, A. R., Ghosal, S., Padhi, K. K., Pandey, L. P. (1998): Mineral element composition of spinach. – J. Sci. Food Agric. 77: 456-458.
[16] Canellas, L. P., Olivares, F. L., Okorokova, A. L., Fa-canha, R. A. (2002): Humic acids isolated from earth-worm compost enhance root elongation, lateral root emergence, and plasma membrane H^+—ATPase activity in maize roots. – J. Plant Physiol. 130: 1951-1957.
[17] Capowiez, Y., Cadoux, S., Bouchand, P., Roger-Estrade, J., Richard, G., Boizard, H. (2009): Experimental evidence for the role of earthworms in compacted soil regeneration based on field observations and results from a semi-field experiment. – Soil Biol. Biochem. 41: 711-717.
[18] Chand, S., Pandey, A., Anwar, M., Patra, D. D. (2011): Influence of integrated supply of vermicompost, biofertilizer and inorganic fertilizer on productivity and quality of rose scented geranium (*Pelargonium species*). – Indian J. Nat. Prod. Resour. 2: 375-382.
[19] Chaoui, H. I., Zibilske, L. M., Ohno, T. (2003): Effects of earthworms casts and compost on soil microbial activity and plant nutrient availability. – Soil Biology and Bio Chemistry 35: 295-302.
[20] Durak, A., Altuntaş, Ö., Kutsal, İ. K., Işık, R., Karaat, F. E. (2017): The effects of vermicompost on yield and some growth parameters of lettuce. – Turk. J. Agric. Food Sci. Technol. 5: 1566-1570.
[21] Edwards, C. A. (1995): Historical overview of vermicomposting. – Biocycle 36: 56-58.
[22] Edwards, C. A., Burrows, I. (1988): The Potential of Earthworms Composts as Plant Growth Media. – In: Edward, C. A., Neuhauser, E. F. (eds.) Earthworms in Waste and Environmental Management. SPB Academic Publishing, The Hague, The Netherlands.
[23] Edwards, C. A., Domínguez, J., Arancon, N. Q. (2004): The Influence of Vermicomposts on Plant Growth and Pest Incidence. – In: Shakir, S. H., Mikhaïl, W. Z. A. (eds.) Soil Zoology for Sustainable Development in the 21st Century. Self-published, Cairo, Egypt.
[24] Gajalakshmi, S., Abbasi, S. A. (2002): Effect of the application of water hyacinth compost/vermicompost on the growth and flowering of Crossandra undulaefolia, and on several vegetables. – Bioresour. Technol. 85: 197-199.
[25] Gandhi, M., Sangwan, V., Kapoor, K. K., Dilbaghi, N. (1997): Composting of household wastes with and without earthworms. – Environ. Ecol. 15: 432-434.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_70017016

[26] Gee, G. W., Bauder, J. W. (1986): Particle-Size Analysis. – In: Klute, A. (ed.) Methods of Soil Analysis (2nd ed., Part 1). Physical and Mineralogical Methods. Agron. Monogr. 9; ASA–SSA, Madison, WI, USA.
[27] Ghabbour, S. I. (1973): Earthworm in agriculture: A modern evaluation. – Indian Rev. Ecol. Biol. Soc. 111: 259-271.
[28] Gutie'rrez-Miceli, F. A., Moguel-Zamudio, B., Abud-Archila, M., Gutie'rrez-Oliva, V. F., Dendooven, L. (2008): Sheep manure vermicompost supplemented with a native diazotrophic bacteria and mycorrhizas for maize cultivation. – Bioresour. Technol. 99: 7020-7026.
[29] Hadi, M. R. H. S., Darz, M. T., Ghandehari, Z., Riazi, G. (2011): Effects of vermicompost and amino acids on the flower yield and essential oil production from Matricaria chamomile L. – J. Med. Plants Res. 5: 5611-5617.
[30] Jablonska-Ceglarek, R., Rosa, R. (2001): Production effects of green fertilizers in the form of forecrops in vegetable cultivation. – Electron. J. Pol. Agric. Univ. Ser. Hortic. 4.
[31] Jaworska, G., Kmiecik, W. (1999): Effect of the date of harvest on the selected traits of the chemical composition of spinach (*Spinacia oleracea* L.) and New Zealand spinach (*Tetragonia expansa* Murr.). – Acta Agrar. Silv. Ser. Agrar. 37.
[32] Joshi, R., Singh, J., Vig, A. P. (2015): Vermicompost as an effective organic fertilizer and biocontrol agent: Effect on growth, yield and quality of plants. – Rev. Environ. Sci. Biotechnol. 14: 137-159.
[33] Julka, J. M. (2001): Earthworm Diversity and Its Role in Agroecosystem. VII National Symposium on Soil Biology and Ecology. – Bangalore University of Agricultural Sciences, Bangalore, pp. 13-17.
[34] Kacar, B. (1995): Soil Analysis. – Chemical Analyses of Plant and Soil: III. – Agriculture Faculty, Ankara University, Turkey.
[35] Kacar, B., Inal, A. (2008): Plant Analysis. – Nobel Press, Ankara, Turkey.
[36] Kansal, B. D., Singh, B., Bajaj, K. L., Kaur, G. (1981): Effect of different levels of nitrogen and farmyard manure on yield and quality of spinach (*Spinacea oleracea* L.). – Plant Foods Hum. Nutr. 31: 163-170.
[37] Karaman, M. R., Adiloglu, A., Brohi, R., Günes, A., İnal, A., Kaplan, M., Zengin, M. (2012): Bitki besleme (Plant Nutrition). – Dumat Ofset, Ankara (Gübretaş Rehber Kitaplar Dizisi, Gubretas Guidebook Series 2.)
[38] Karmegam, N., Alagumalai, K., Daniel, T. (1999): Effect of vermicompost on the growth and yield of green gram (*Phaseolus aureus* Roxb.). – Trop. Agric. 76: 143-146.
[39] Knudsen, D., Peterson, G. A., Pratt, P. F. (1982): Lithium, sodium, and potassium. – In: Page, A. L. (ed.) Methods of Soil Analysis; Part 2. Chemical and Microbiological Properties, (methodsofsoilan2). American Society of Agronomy, Madison, WI, USA, pp. 225-246.
[40] Lazcano, C., Arnold, J., Tato, A., Zaller, J. G., Domín-guez, J. (2009): Compost and vermicompost as nursery pot components: Effects on tomato plant growth and morphology. – Span. J. Agric. Res. 7: 944-951.
[41] Lazcano, C., Sampedro, L., Zas, R., Domínguez, J. (2010): Vermicompost enhances germination of the mari-time pine (*Pinus pinaster* Ait.). – New For. 39: 387-400. DOI: 10.1007/s11056-009-9178-z.
[42] Li, K., Li, P. Z. (2010): Earthworms helping economy, improving ecology and protecting health. – Int. J. Environ. Eng. 10: 354-365.
[43] Lindsay, W. L., Norvell, W. A. (1978): Development of a DTPA soil test for zinc, iron, manganese, and copper. – Soil Sci. Soc. Am. J., 42: 421-428.
[44] Mackey, A. D., Syres, J. A., Greeg, P. E. H. (1982): Plant availability of phosphorus in superphosphate and phosphate rock as influenced by earthworms. – Soil Biochem. 14: 281-287.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_70017016

[45] Moghadam, A. R. L., Ardebili, Z. O., Saidi, F. (2012): Vermicompost induced changes in growth and development of Lilium Asiatic hybrid var. Navona. – Afr. J. Agric. Res. 7: 2609-2621.
[46] Molerock, T. E., Correll, J. C. (2008): Vegetables I. *Asteracea*, *Brassicaceae*, *Chenopodicaceae*, and *Cucurbitaceae*. – Prohens, J., Nuez, F. (eds.) Handbook of Plant Breeding. Springer, Berlin, Germany.
[47] Moraditochaee, M., Bozorgi, H. R., Halajisani, N. (2011): Effects of vermicompost application and nitrogen fertilizer rates on fruit yield and several attributes of eggplant (*Solanum melongena* L.) in Iran. – World Appl. Sci. J. 15: 174-178.
[48] Mycin, T. R., Lenin, M., Selvakumar, G., Thangadurai, R. (2010): Growth and nutrient content variation of groundnut Arachis hypogaea L. under vermicompost application. – J. Exp. Sci. 1: 12-16.
[49] Nardi, S., Pizzeghello, D., Muscolo, A., Vianello, A. (2002): Physiological effects of humic substances on higher plants. – Soil Biol. Biochem. 34: 1527-1536.
[50] Narwal, S. S. (2010): Allelopathy in ecological sustainable organic agriculture. – Allelopath. J. 25: 51-72.
[51] Olsen, S. R., Dean, L. A. (1965): Phosphorus. – In: Black, C. A. (ed.) Methods of Soil Analysis, Part 2. American Society of Agronomy, Madison, WI, USA.
[52] Pant, A. P., Radovich, T. J. K., Hue, N. V., Talcott, S. T., Krenek, K. A. (2009): Vermicompost extracts influence growth, mineral nutrients, phytonutrients and antioxidant activity in pak choi (*Brassica rapa* cv. Bonsai, Chinensis group) grown under vermicompost and chemical fertilizer. – J. Sci. Food Agric. 89: 2383-2392.
[53] Papathanasiou, F., Papadopoulos, I., Tsakiris, I., Tamoutsidis, E. (2012): Vermicompost as a soil supplement to improve growth, yield and quality of lettuce (*Lactuca sativa* L.). – J. Food Agric. Environ. 10: 677-682.
[54] Peyvast, G., Olfati, J. A., Madeni, S., Forghani, A. (2007): Effect of vermicompost on the growth and yield of spinach (*Spinacia oleracea* L.). – J. Food Agric. Environ. 6: 132-135.
[55] Peyvast, G., Olfati, J. A., Madeni, S., Forghani, A., Samizadeh, H. (2008): Vermicompost as a soil supplement to improve growth and yield of parsley. – Int. J. Veg. Sci. 14: 82-92.
[56] Plank, M. J. (1992): U.S. Shoring Shield. – U.S. Patent No. 5,096,334.
[57] Richards, L.A. (1954): Diagnosis and Improvement of Saline Alkali Soils. – USDA Handbook, No: 60. United States Department of Agriculture, Washington, DC, USA.
[58] Şalk, A., Arın, L., Deveci, M., Polat, S. (2008): Özel sebzecilik. – Tekirdağ, Turkey.
[59] Scheu, S. (1987): Microbial activity and nutrient dynamics in earthworms casts. – J. Biol. Fertil. Soil. 5: 230-234.
[60] Scialabba, N., Hattam, C. (2002): Organic Agriculture, Environment and Food Security. – Environment and Natural Resources Series. Food and Agriculture Organization of the United Nations (FAO), Rome.
[61] Seufert, V., Ramankutty, N., Mayerhofer, T. (2017): What is this thing called organic?– How organic farming is codified in regulations. – Food Policy 68: 10-20.
[62] Shadanpour, F., Mohammadi, T. A., Hashemi, M. K. (2011): Marigold: The possibility using vermicompost as the growth medium. – J. Ornam. Hortic. Plants 1: 153-160.
[63] Singh, R., Sharma, R. R., Kumar, S., Gupta, R. K., Patil, R. T. (2008): Vermicompost substitution influences growth, physiological disorders, fruit yield and quality of strawberry (*Fragaria* × *ananassa* Duch.). – Bioresour. Technol. 99: 8507-8511.
[64] Stevenson, F. J. (1991): Organic Matter—Micronutrient Reactions in Soil. – In: Mortvedt, J. J., Cox, F. R., Shuman, L. M., Welch, R. M. (eds.) Micronutrients in Agriculture. Soil Science Society of America, Madison, MI, USA.
[65] Stinner, B. R., House, G. J. (1987): Role of ecology in lower input, sustainable agriculture: An introduction. – Am. J. Altern. Agric. 2: 146-147.
[66] Suhane, R. K. (2007): Vermicompost. – Rajendra Agriculture University, Pusa, India.
[67] Tilman, D. (1998): The greening of the green revolution. – Nature 396: 211-212.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_70017016

[68] Uma, B., Malathi, M. (2009): Vermicompost as a soil supplement to improve growth and yield of Amaranthus species. – Res. J. Agric. Biol. Sci. 5: 1054-1060.
[69] Vijaya, D., Padmadevi, S. N., Vasanda, S., Meerabhai, R. S., Chellapandi, P. (2008): Vermicompost induced changes in growth and development of Lilium Asiatic hybrid var. – Navona J. Org. Syst. 3: 51-56.
[70] Vijaya, K. S., Seethalakshmi, S. (2011): Contribution of Parthenium vermicompost in altering growth, yield and quality of *Alelmoschus esculentus* (I) Moench. – Adv. Biotechnol. 11: 44-47.
[71] Vivas, A., Moreno, B., Garcia-Rodriguez, S., Benitez, E. (2009): Assessing the impact of composting and vermicomposting on bacterial community size and structure, and microbial functional diversity of an olive-mill waste. – Bioresource Technology 100(3): 1319-1326.
[72] Willer, H., Lernoud, J. (2015): The World of Organic Agriculture - Statistics and Emerging Trends 2015. – FiBL & IFOAM Frick, Switzerland.
[73] Zaller, J. G. (2007): Vermicompost as a substitute for peat in potting media: Effects on germination, biomass alloca-tion, yields and fruit quality of three tomato varieties. – Sci. Hortic. 112: 91-199. DOI: 10.1016/j.scienta.2006.12.023.