Original scientific paper
Journal of Central European Agriculture, 2020, 21(1), p.104-112
DOI: /10.5513/JCEA01/21.1.2121

Effects of vermicompost produced from cow manure on the growth, yield and nutrition contents of cucumber (*Cucumis sativus*)

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Received: May 18, 2018; accepted: April 25, 2019

ABSTRACT

An experiment was conducted to determine the effects of vermicompost on the growth, yield and nutrient contents of cucumber grown under the glasshouse conditions. This experiment was performed in completely randomized design with five replications. The base medium (control) was selected to be a mixture of 75% farm soil with 25% sand that had been substituted with 0, 10, 20, 30, 40, 50 and 60% by volume of cow manure vermicompost. The highest leaf area, stem numbers, stem and root dry weight, fruit yield, and chlorophyll content were resulted from substitution of base medium with10 and 20% vermicompost that were significantly different from control ($P \leq 0.05$). Further, increase in the vermicompost content of the base medium, reduced the stem height, leaf area, stem dry weight, root dry weight, and chlorophyll content. Plant yield was the lowest in the 50% and 60% vermicompost medium. Shoot macro and micro-nutrient content such as nitrogen, phosphorus, potassium, calcium, iron, zinc, manganese, and copper increased significantly in response to the increase in vermicompost ratio from 0 to 60%, therefore, the lowest and the highest of these nutrient contents were observed in the control and 60% vermicompost, respectively, and even in some cases, nutrients content reached the toxic levels.

Keywords: biofertilizer, chlorophyll index, fruit yield, organic farming, soil fertility

INTRODUCTION

The organic manure is a handy, low-cost source of nutrition compare to the inorganic fertilizers. The commercial values (Haque, 2000). Low cost crop production can be achieved via application of organic compounds instead of high valuable inorganic fertilizers. Ability of some species of earthworm to consume and breakdown a wide range of organic residues such as sewage sludge, animal wastes, crop residues and industrial waste have been already reported (Edwards, 1985; Dominguez et al., 1997; Kaushik and Garg, 2003). Organic farming system relies on large-scale application of animal wastes, compost, crop rotation, crop residues, green manure, vermicompost, biofertilizers VAM, bio pesticides, and biological control (Kannan et al., 2005). Utilization of high yielding varieties, high quality chemical fertilizers, as well as pesticides application have enabled Iran to become a self-sufficient country in food grains production. The enhancement of plant productivity via increasing the chemical fertilizers and chemical pesticides might cause crucial harm effects on health and environment (Alam et al., 2007). Application of vermicompost in large-scale for vegetable production could settle the problem of wastes disposal and solve the shortage of organic matter in soil (Kannan et al., 2005).

Vermicompost is a good source of different macro and micronutrients, particularly Nitrogen (N), Phosphorus (P), Potassium (K), and Sulfur (S). Earthworms have been described as being one of the main and dominant soil fauna of class oligochaeta in Phylum annelida and are known for their role in soil formation (Kale, 1998). Earthworms ingest a large amount of organic matter and excrete it as cast and this cast include several enzymes and abounding in plant nutrients, useful bacteria and mycorrhizae (Reddy and Reddi, 2002). Various greenhouse and field studies have examined the effects of a variety of vermicomposts on a lot of crops including cereals and legumes (Kaushik and Garg, 2003), vegetables (Wilson and Carlile, 1989; Tomati et al., 1990; Subler et al., 1998), ornamental and flowering plants (Atiyeh et al., 2000), and field crops (Arancon et al., 2004). Nath and Singh (2009) reported that treatments of vermiwash (extract from different animal, agro and kitchen wastes (increased growth and productivity of okra, beans, and radish. Application of vermicompost increases the total microbial population of N-fixing bacteria and actinomycetes. The increase in microbial activity causes improve in soil P and N availability (Alam, 2007).

Vermicompost have been widely applied in traditional agriculture and horticulture and its beneficial effects have been proven on soil biota and soil structure. It is obvious that organic farming is not a destination, but it is an imperative. The excessive use agrochemicals and fertilizers in green revolution have increased environmental pollution and thus threatened the fragile ecosystems. Organic farming conserves soil fertility and has soil erosion through implementation of proper conservation principles. The purpose of this study was to investigate the effects of cow manure vermicompost products, as an organic compound, on cucumber productivity.

MATERIAL AND METHODS

An experiment was conducted to evaluate the effect of the vermicompost of cow manure origin, on the nutrients status, growth, and yield of cucumber grown under glasshouse conditions in the University of Mohaghegh Ardabili, Iran. This experiment was conducted in completely randomized design with five replications. The base medium (control treatment) was a mixture of 75% farm soil and 25% sand. The treatment media was vermicompost (Zarrin Kood Company, Gorgan; Iran) incorporated at six rates (10, 20, 30, 40, 50 and 60% (v)) treatment. Cucumber seeds were placed into the germinator, and then two seeds were planted in the seedling plastic pots of 500 g in the cultivation environments with 0, 10, 20, 30, 40, 50 and 60%, of vermicompost while the medium of the base cultivation consisted of three soil portions (supplied from Now Shahr, Iran) and one sand portion (Control). Prior to seed cultivation, the cultivation medium was Physico-biochemically evaluated (Tables 1 and 2).

Once the plants produced their third real leaf, they were planted into the 20 kg pots, containing the base medium of soil and sand with different vermicompost levels. In order to measure the leaves area, in the end of the growth period, the leaves were separated from stems and were measured their surface area with leaf area meter. The chlorophyll index of the leaves was measured by SPAD chlorophyll-meter. Dry weight of roots and stems were measured after drying in oven (78 and 80°C, respectively) for 24 and 48 hours.

The basic medium and different vermicompost treatments were air-dried and passed through a 2-mm sieve for analysis before plant cultivation. Electrical conductivity (EC) and pH of the treatments were measured by EC and pH meters in saturated paste extract. Organic matter content was determined by the Walkley-Black method. The available macro-nutrients and micronutrient in different medium were extracted by the following methods: Phosphorus by Olsen's procedure, exchangeable Potassium, Calcium and Magnesium by ammonium acetate, and the micronutrients by DTPA (Diethylenetriamine pentaacetic acid). Nitrogen, phosphorus, potassium, Calcium and Magnesium in dried samples of shoots were determined by Kjeldahl method, spectrophotometric method, flame emission spectrophotometric method and EDTA titrimetric method respectively (Jones, 2001). The micronutrient concentration was analyzed using atomic absorption spectroscopy after dry ashes at 550°C for five hours (Jones, 2001).

Table 1. Measured quantities of chemical properties of the elements existing before plant cultivation in different cultivation environments

Treatment	Organic carbon (%)	N (%)	P ($mg*kg^{-1}$)	K ($mg*kg^{-1}$)	Ca ($meq*l^{-1}$)	Mg ($meq*l^{-1}$)
Control	1.7	0.063	29.03	210	9.2	4.63
V1	2.1	0.25	31.33	620	21	6.79
V2	2.6	0.39	33.88	1,285	28	14.65
V3	2.7	0.45	40.4	1,850	28.7	15.35
V4	3.1	0.56	46.54	2,700	29.5	16.12
V5	3.6	0.65	53.52	4,002	30.4	17.32
V6	4.5	0.75	59.6	5,250	32	19.6
Vermicompost	8.3	1.8	69.7	340	20	22

V1 - 10% vermicompost, V2 - 20% vermicompost, V3 - 30% vermicompost, V4 - 40% vermicompost, V5 - 50% vermicompost and V6 - 60% vermicompost

Table 2. Measured quantities of chemical properties of the elements existing before plant cultivation in different cultivation environments

Treatment	Fe ($mg*kg^{-1}$)	Mn ($mg*kg^{-1}$)	Zn ($mg*kg^{-1}$)	Cu ($mg*kg^{-1}$)	pH	EC ($mmho*cm^{-1}$)
Control	4.99	2.24	0.76	1.6	7.94	1.6
V1	7.54	2.59	1.23	1.78	7.8	2
V2	10.15	3.17	2.2	1.95	7.68	2.2
V3	12.22	4.4	3.63	2.08	7.63	2.3
V4	14.25	5.14	3.1	2.15	7.6	4
V5	17.2	8.49	3.93	2.22	7.56	4.8
V6	19.49	12.84	4.72	2.34	7.55	5.6
Vermicompost	26.54	18.25	8.75	2.55	7.84	7.2

V1 - 10% vermicompost, V2 - 20% vermicompost, V3 - 30% vermicompost, V4 - 40% vermicompost, V5 - 50% vermicompost and V6 - 60% vermicompost. EC - electrical conductivity

STATISTICAL ANALYSIS

Data analysis was done using SAS V9.2 software (SAS Institute Inc., Cary, NC, USA). Mean comparison of treatments were done using Duncan's multiple range test at 1 and 5 % levels.

RESULTS AND DISCUSSION

Growth and yield

Results indicated that application of vermicompost showed a significant effect on the plant height, leaf area, shoot dry weight, chlorophyll index, and fruit yield ($P \leq 0.01$; Table 3).

Plant height

The results showed that the application of vermicompost resulted in a significant increase in cucumber plant height. The plants in 20% vermicompost beds, showed the greatest height (2.3 m), which did not show a significant different with the height of the plants grown in 10% vermicompost bed (2.15 m). There was no significant difference with the plant height of the control and plants in 30% vermicompost containing bed. The results showed that the application of vermicompost at high levels (more than 30%) reduced the plant height and the shortest plants were observed in the treatment with 60% vermicompost (Table 4). Hameeda et al. (2007) and Chamani et al. (2008) reported similar results on sorghum and petunia, respectively.

Leaf area

The largest leaf area was observed in the plants that grow in the cultivation bed treated with 20% vermicompost (5,679 cm^2) which was not significantly different from the plants grown in the treatment with 10% vermicompost (5,662 cm^2). Additionally the leaf area of the treated plants with 30% vermicompost (4,640 cm^2), was not significantly different from the leaf area of the control plants (4,590 cm^2). The leaves area drastically decreased in treatment with 40, 50 and 60% vermicompost and the lowest leaf area (580 cm^2) was observed in the plants of the cultivation bed with 60% vermicompost (Table 4). Similar results have been reported by Arancon et al. (2006).

Root dry weight

The mean comparison of results showed that the highest root dry weight (27 g) was produced in plants grown in the cultivation medium containing 20%vermicompost, which was not significantly different from plants cultivated in 10% containing vermicompost (25.8 g). There was a decrease in the root dry weight at higher proportions of vermicompost added to the cultivation bed and the lowest root dry weight was produced in 60% vermicompost treatment (Table 4). Zaller (2007) has reported similar results. Sainz et al. (1998) after studying the effect of increasing vermicompost levels (0, 10, 50 and 100%) and urban wastewaters on growth and nutrition of clover and cucumber, reported that application of vermicompost in the soil significantly increased the dry

Table 3. Analysis of variance of vermicompost effect on growth and yield of greenhouse cucumber

Source of variation	df	Plant height	Leaf area	Root dry weight	Stem dry weight	Chlorophyll	Fruit yield
Treatment	6	2.6**	21,750,947.1**	186.92**	96,952.24**	733.13**	10.31**
Error	28	0.044	222,057.4	14.456	1,749.88	82.22	0.25
CV (%)	-	3.14	12.93	19.9	17.41	20.7	19.6

**Significant at P≤0.01

Table 4. Mean comparison of vermicompost effect on growth and yield of greenhouse cucumber

Vermicompost levels (%)	Plant height (m)	Leaf area (cm^2)	Root dry weight (g)	Stem dry weight (g)	Chlorophyll index (SPAD)	Fruit yield (kg/plant)
0	2^{b}	$4,590^{b}$	17.6^{cd}	271^{b}	20.94^{c}	5.6^{b}
10	2.16^{a}	$5,622^{a}$	25.8^{ab}	393^{a}	45.8^{ab}	4.76^{bc}
20	2.3^{a}	$5,670^{a}$	27^{a}	416^{a}	55.1^{a}	9.2^{a}
30	1.9^{b}	$4,640^{b}$	21^{bc}	260^{b}	55.8^{a}	5.9^{b}
40	1.7^{c}	$3,320^{c}$	17.2^{cd}	182.2^{c}	49.2^{ab}	4.5^{bc}
50	1.4^{d}	$1,650^{d}$	14.8^{d}	137.5^{d}	46.4^{b}	2.8^{c}
60	0.8^{e}	580^{e}	9.6^{e}	69.6^{e}	34.8^{b}	1.05^{d}

Numbers with the same letter, have no significant difference and fresh weight of clover and cucumber. Adinarayana and Kumar (2006) showed that application of vermicompost in the soil resulted in Zn uptake incensement. Based on the results of this study and similar findings of other above-mentioned experiments, it can be concluded that application of organic matters such as vermicompost enhances root growth through improving the soil texture and increasing the capacity of soil to hold moisture.

Stem dry weight

The highest stem dry weight (416 g) was observed in the plants grown in the cultivation bed treated with 20% vermicompost that was not significantly different with 10% vermicompost treatment (393 g). The control and 30% vermicompost treatments were ranked next and their stem dry weights were 271 g and 260 g respectively. There was a decrease in the stem dry weight related to the higher levels of vermicompost, where the lowest stem dry weight was in the 60% vermicompost treatment (Table 4). Arancon et al. (2006) studied the effects of the adding 5-15 ton. ha^{-1} vermicompost onto strawberry, and found out that vermicompost application increased the dry weight of stems as well as the aerial parts. Same results were reported by Hameeda et al. (2007). Subler et al. (1998) reported that a soil containing up to 10% of added pig vermicompost significantly increased biomass of tomato. Bachman and Metzger (2007) in an investigation focused on the effect of vermicompost application in seed beds of seasonal plants, such as tomato and pepper argued that the fresh and dry weight of aerial parts and leaf area of the plants grown on beds containing vermicompost increased by 40%.

Chlorophyll index

The results showed that application of vermicompost, in the cultivation medium increased chlorophyll index significantly. The highest chlorophyll index (55.68 SPAD) was observed in 30% vermicompost treated plants which did not show a significant different with 10%, 20%, 40% vermicompost treatments. In respect of this trait, the treatments with 50% and 60% vermicompost did not have a serious discrepancy (Table 4).

Fruit yield

The highest fruit yield (9.2 kg per plant) was obtained in plants grown in the cultivation bed treated with 20% vermicompost. The fruit yield of plants treated with 30% vermicompost was significantly decreased and 60% vermicompost treatment produced the lowest fruit yield (1.05 kg per plant). Higher percentages of vermicompost, reduced fruit yield. This can be due to the increase in electrical conductivity and decrease in drainage of the cultivation bed (Table 4). The findings of this research is consistent with findings of Alam et al. (2007), Azarmi et al. (2008) and Suthar (2009).

Nutrition status

Based on analysis of data variance (Tables 5 and 6), application of vermicompost significantly affected the content of plant nutrients content, including N, P, K, Mg, Ca, Fe, Zn, Cu, and Mn.

Nitrogen

Results showed that adding vermicompost to the soil has increased the content of N in aerial part of cucumber. The lowest content of N was obtained in control (soil + sand), and increasing vermicompost levels in the soil, significantly increased the percentage of N in aerial part of the plant. The highest value for this element was obtained in the soil containing 60% vermicompost (Table 7). Arancon et al. (2004) in an experiment on the influences of vermicompost, produced from food waste and paper waste, on field strawberries showed that vermicompost in addition to increasing yield of the crop, increased the absorption of N. Senthilkumar et al. (2004) reported that vermicompost led to a significant increase of N concentration in the leaves. In their experiment, N concentration of tomato that grown in culture media containing 10, 25, 50 and 100% vermicompost was significantly higher than tomato grown in culture media containing 0 and 5% vermicompost.

Phosphorus

Based on the results, increased proportion of vermicompost in seed bed has led to the increased

Table 5. Analysis of Variance of effect of vermicompost on content elements of cucumber shoots

Source of Variation	df	N	P	K	Mg	Ca
Treatment	6	19.84**	0.19**	16.34*	8.55**	42.48**
Error	28	0.152	0.005	0.273	0.29	1.61
CV (%)	-	8.51	12.81	8.89	12.90	6.68

**Significant at P≤0.01

Table 6. Analysis of Variance of effect of vermicompost on content elements of cucumber shoots

Source of Variation	df	Fe	Cu	Zn	Mn
Treatment	6	1,807.3**	956.7**	1,620.4**	2,023.65**
Error	28	92.45	32.46	76.8	56.25
CV (%)	-	5.54	14.1	13.3	11.2

**Significant at P≤0.01

Table 7. Mean comparison of effect of vermicompost on content elements of cucumber shoots

Vermicompost levels (%)	N (%)	P (%)	K (%)	Mg (%)	Ca (%)
0	1.46^{f}	0.25^{e}	3.34^{f}	0.27^{d}	1.14^{d}
10	2.78^{e}	0.41^{d}	4.5^{e}	0.37^{c}	1.26^{d}
20	4.01^{d}	0.53^{c}	5.04^{e}	0.42^{c}	1.46^{c}
30	4.78^{c}	0.56^{c}	5.74^{d}	0.54^{b}	1.67^{b}
40	5.34^{b}	0.66^{b}	6.44^{c}	0.57^{b}	1.76^{b}
50	6.66^{a}	0.69^{b}	7.38^{b}	0.66^{a}	1.77^{b}
60	6.96^{a}	0.86^{a}	8.68^{a}	0.7^{a}	1.92^{a}

Numbers with the same letter have no significant difference.

amount of P in plant aerial part. The highest and lowest amount of P in aerial parts of cucumber was obtained in 60% vermicompost treatment and control, respectively. The amount of P in aerial parts of cucumber was not significantly different in cultivation bed treated with the 20 and 30% of vermicompost (Table 7). Arancon et al. (2004) reported that vermicompost increased the absorption of P. Edwards and Burrows (1988) showed that vermicomposts supply nutrients such as N, available P, K, Ca and Mg for plant. Senthilkumar et al. (2004) reported that amounts of available N, P and K were higher in blocks containing vermicompost.

Potassium

Mean comparison of the treatments showed that plants grown on control (without vermicompost) had lowest K content in their aerial part; however, increasing amount of vermicompost in the soil increased the K content. There was not a significant difference between 10 and 20% vermicompost treatments, and the highest amount of K was observed in 60% vermicompost treatment (Table 7). Kumari and Ushakumari (2002) by examining the application of vermicompost on yield and uptake of nutrients in cowpea demonstrated that application of enriched vermicompost increased the plant uptake of K and Mg and other micronutrients compared to the control. The Increase in plant uptake of nutrients by application of vermicompost may be due to its high available nutrient content.

Magnesium

The results revealed that increasing proportion of vermicompost in soil increased Mg content of the plant aerial part. The highest amount of Mg was obtained in treatment with 60% vermicompost, which did not show a significant difference with 50% vermicompost treatment (Table 7). Kumari and Ushakumari (2002) indicated that application of vermicompost increased the plant Mg uptake and other micronutrients compare to control.

Calcium

The lowest Ca content was obtained in shoot of the plants grown in control bed. The results showed that increase in vermicompost levels in seed bed, led to the increased amount of Ca in cucumber shoot, although the amount of calcium in 10% treatment was not significantly different with control. In addition, plants grown on soil containing 30, 40 and 50% vermicompost did not significantly differ in terms of Ca content of shoot. The highest amount of Ca was obtained in 60% vermicompost treatment (Table 7). Kumari and Ushakumari (2002) demonstrated that application of enriched vermicompost increased the plant uptake of Ca and micronutrients compared with control.

Iron

The results showed that the highest level of Fe in cucumber shoot belonged to 60% vermicompost treatment, which had no significant difference with the levels of 40% and 50% (Table 8), while the lowest Fe content was obtained in plants grown in control bed. Increasing proportion of vermicompost in soil increased Fe content in plant shoots, though the amount of Fe in 10% treatment was not significantly different compare to control. However, the difference between 10% and 20% vermicompost treatments was significant. Adinarayana and Kumar (2006) were reported similar results.

Copper

Plants grown on control bed had the lowest copper (Cu) content in their aerial parts. Increasing the proportion of vermicompost from 0 to 60% in soil, enhanced the Cu content in plant shoots, nevertheless, treatments of 30, 40 and 50% vermicompost were not significantly different. The highest Cu content was found in aerial parts of the plant grown on 60% vermicompost treatment (Table 8).

Zinc

Based on the results of Table 8, plants grown on control bed had the lowest Zn content in their aerial parts. Increase in the vermicompost level from 0 to 60% in soil, led to the increase in Zn content, though 10 and 20% vermicompost treatments did not indicate a significant difference. Likewise, there was not a significant difference between 20, 30 and 40% treatments. Adinarayana and Kumar (2006) showed that application of vermicompost to the soil increased plant Zn uptake (Table 8). Adding vermicompost to the land and accordingly the increase in Fe and Zn plant uptake is due to mineralization of organic matters, decreased pH of soil by organic acids, and increase in formation of micronutrient complexes. Although the higher proportions of vermicompost in the soil means a higher amount of nutrients, reduction of pH soil and causes increased water holding capacity for a longer period in such soils but leads to increased electrical conductivity (EC) of the cultivation medium, which in turn results in decreased growth and yield of the plants (Adinarayana and Kumar, 2006).

Manganese

Plants grown on control bed (without vermicompost) had the lowest Mn content. Increasing proportion of

Table 8. Mean comparison of effect of vermicompost on content elements of cucumber shoots

Vermicompost levels (%)	Fe (mg*kg^{-1})	Cu (mg*kg^{-1})	Zn (mg*kg^{-1})	Mn (mg*kg^{-1})
0	141.2^{c}	17.67^{e}	38.06^{f}	38.19^{e}
10	153.6^{c}	27.41^{d}	50.9^{e}	47.5^{e}
20	175.72^{b}	36^{c}	59.88^{de}	58.38^{d}
30	178.26^{b}	47^{b}	66.06^{cd}	68.96^{c}
40	183.42^{ab}	48.2^{ab}	75^{bc}	77.46^{bc}
50	187.5^{ab}	51.4^{ab}	81.6^{ab}	84.82^{ab}
60	193.6^{a}	55.16^{a}	89.96^{a}	93.7a

Numbers with the same letter, have no significant difference

vermicompost in soil from 0 to 60% increased the Mn content of plants. There was not a significant difference between 30 and 40%; 40 and 50%, as well as 50 and 60% treatments and the highest value of Mn was detected in 60% vermicompost treatment (Table 8).

CONCLUSIONS

The results of this research indicated that the application of vermicompost of cow manure, instead of the soil, at 10% and 20% to the cultivation bed that consists of 75% soil and 25% sand, caused an increase in the growth indexes such as the plant height, root and stem dry weight, leaf chlorophyll content, and fruit yield of greenhouse cucumber. Furthermore, vermicompost significantly affected the content of plant nutrients such as N, P, K, Mg, Ca, Fe, Zn, Cu, and Mn. Taken together, results of this research and other above-mentioned findings, indicated that application of organic materials, such as vermicomposts, cause the improvement of soil fertility as well as the increase in the soil capacity to keep humidity, therefore the root growth improves. Using annually 29% volume of vermicompost to the soil, causes an adequate increase in the activities of the soil enzymes which give to the plant development, N, and P efficiency. Thus applying the proper rates of vermicompost, increases the cucumber yield, improve the soil properties, and reinforce the soil biologically.

REFERENCES

Adinarayana, V., Kumar, S.T. (2006) Effect of applied phosphorus and vermicompost on removal of heavy metals by leafy vegetables in polluted soil. In: Proceedings of the 18th World congress of soil science (WCSS), Philadelphia, Pennsylvania, USA, 9-15 July 2006, International Union of Soil Science, 650-654.

Alam, M.N., Jahan, M.S., Ali, M.K., Islam, M.S., Khandaker, S.M.A.T. (2007) Effect of vermicompost and NPKS fertilizers on growth, yield and yield components of red amaranth. Australian Journal of Basic and Applied Sciences, 1 (4), 706-716. Available at: http://ajbasweb.com/old/ajbas/706-716.pdf

Arancon, N.Q., Edward, C.A., Bierman, P. (2006) Influence of vermicomposts on field strawberries: part 2. Effect on soil microbiological and chemical properties. Bioresource Technology, 97, 831-840. DOI: https://doi.org/10.1016/j.biortech.2005.04.016

Arancon, N.Q., Edwards, C.A., Bierman, P., Welch, C., Metzger, J.D. (2004) Influences of vermin composts on field strawberries: Effects on growth and yields. Bioresource Technology, 93, 145-153. DOI: https://doi.org/10.1016/j.biortech.2003.10.014

Atiyeh, R.M., Subler, S., Edwards, C.A., Bachman, G., Metzger, J.D., Shuster, W. (2000) Effects of vermicomposts and composts on plant growth in horticultural container media and soil. Pedobiologia, 44 (5), 579-590. DOI: https://doi.org/10.1078/S0031-4056(04)70073-6

Azarmi, R., Torabi Giglou, M., Didar Taleshmikail, R. (2008) Influence of vermicompost on soil chemical and physical properties in tomato (*Lycopersicum esculentum*) field. African Journal of Biotechnology, 7 (14), 2397-2401. Available at: file:///C:/Users/mehdi/Downloads/59004-106076-1-PB.pdf

Bachman, G.R., Metzger, J.D. (2007) Growth of bedding plants in commercial potting substrate amended with vermicompost. Bioresource Technology, 99 (8), 3155-61. DOI: https://doi.org/10.1016/j.biortech.2007.05.069

Chamani, E., Joyce, D.C., Reihanytabar, A. (2008) Vermicompost effects on the growth and flowering of *Petunia hybrida* 'Dream Neon Rose'. American-Eurasian Journal of Agriculture and Environmental Science, 3 (3), 506-512.

Dominguez, J., Edwards, C.A., Subler, S. (1997) A comparison of vermicomposting and composting methods to process animal wastes. Bio-Cycle, 38, 57- 59.

Edwards, C.A (1985) Production of Feed Protein by Animal Waste from Earthworm. Philosophical Transactions of The Royal Society B Biological Sciences, London B, 310 (1144), 299-307. DOI: https://doi.org/10.1098/rstb.1985.0120

Edwards, C.A., Burrows, I. (1988) The potential of earthworm composts as plant growth media. In: Edwards, C.A., Neuhauser, E. (eds) Earthworms in Waste and Environmental Management. SPB Academic Press, The Hague, The Netherlands, 21–32.

Hameeda, B., Harini, G., Rupela, O.P., Reddy, G. (2007) Effect of composts or vermicomposts on sorghum growth and mycorrhizal colonization. African Journal of Biotechnology, 6 (1), 9-12. Available at: http://www.academicjournals.org/article/article1379768717_Hameeda%20et%20al.pdf

Haque, M.O. (2000) Effects of different fertilizer management practices on the growth and yield of main and ratoon crop of cabbage. Mymensingh: Bangladesh Agricultural University, Department of Horticulture. MS thesis.

Jones, J.B. (2001) Laboratory guide for conducting soil tests and plant analysis. Boca Raton: CRC Press.

Kale, R.D. (1998) Earthworms: Nature's gift utilization of organic wastes. In: Edwards, C.A., ed. Earthworm ecology. Washington: St Lucie Press.

Kannan, P., Saravanan, A., Krishnakumar, S., Natarajan, S.K. (2005) Biological properties of soil as influenced by different organic manures. Research Journal of Agriculture and Biological Sciences, 1 (2), 181-183.

Kaushik, P., Garg, V.K. (2003) Vermicomposting of mixed solid textile mill sludge and cow dung with the epigeic earthworm Eisenia Foetida. Bioresource Technology, 90 (3), 311– 316. DOI: https://doi.org/10.1016/S0960-8524(03)00146-9

Kumari, M.S., Ushakumari, K. (2002) Effect of vermicompost enriched with rock phosphate on the yield and uptake of nutrients in cowpea (*Vigna unguiculata* L. Walp). Journal of Tropical Agricultural Science, 40, 27-30.

Nath, G., Singh, K. (2009) Utilization of vermiwash potential on certain summer vegetable crops. Journal of Central European Agriculture, 10 (4), 417-426. Available at: https://jcea.agr.hr/articles/760_utilization_of_vermiwash_potential_on_certain_summer_vegetable_crops_en.pdf

Reddy, T.Y., Reddi, G.H.S. (2002) Mineral nutrition, manures and fertilizers. In: Reddy, T.Y., Reddi, G.H.S., Principles of agronomy. Ludhiana, India: Kalyani Publishers.

Sainz, M.J., Taboada-Castro, M.T., Vilariño, A. (1998) Growth, mineral nutrition and mycorrhizal colonization of red clover and cucumber plants grown in a soil amended with composted urban wastes. Plant and Soil, 205, 85–92. Available at: https://link.springer.com/article/10.1023/A:1004357330318

Senthilkumar, S., Sriramachandrasekharan, M.V., Haripriya, K. (2004) Effect of vermicompost and fertilizer on the growth and yield of rose. Journal of Interacademicia, 8 (2), 207-210.

Subler, S., Edwards, C.A., Metzger, J.D. (1998) Comparing vermicomposts and composts. Bio-Cycle, 39, 63-66.

Suthar, S. (2009) Impact of vermicompost and composted farmyard manure on growth and yield of garlic (*Allium stivum* L.) field crop. International Journal of Plant Production 3 (1), 1735-8043. Available at: http://ijpp.gau.ac.ir/article_629_d5542c75058a71cac295b7d54eeca069.pdf

Tomati, U., Galli, E., Grappelh, A., Dihena, G. (1990) Effect of earthworm caste on protein synthesis in radish (*Raphanus sativus*) and lettuce (*Lactuca sativa*) seedlings. Biology and Fertility of Soils, 9, 288-289. Available at: https://link.springer.com/article/10.1007%2FBF00634102

Wilson, D.P., Carlile, W.R. (1989) Plant growth in potting media containing worm-worked duck waste. Acta Horticulturae, 238, 205-220. DOI: https://doi.org/10.17660/ActaHortic.1989.238.24

Zaller, J.G. (2007) Vermicompost as a substitute for peat in potting media: Effects on germination, biomass allocation, yields and fruit quality of three tomato varieties. Scientia Horticulturae, 112, 191–199. DOI: https://doi.org/10.1016/j.scienta.2006.12.023