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Vermicompost Leachate a Viable Bio-stimulant for Tomato Growth and Yield (*Solanum lycopersicum*)

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ABSTRACT

Background: The influence of inorganic fertilizer has posed considerable challenges on increasing food production worldwide. A careful plan is required to increase the yield and quality of crops. A profound knowledge on the use of organic manure involvement in plant growth and development could be beneficial for food production. The use of acceptable inorganic and different concentrations of vermicompost has been used in an attempt to enhance crop growth and development with the aim of increasing food production. The aim of the study was to investigate the impact of vermicompost tea concentrate extracted from cow manure and grass cutting on physiological responses of tomato (*Solanum lycopersicum)*.Vegetative growth and yield of tomato was stimulated by mineralization of organic waste coupled with the mesophilic action of earthworm. Vermicompost is a by-product of earthworm tissues. It is a nutrient source rich in essential components for plant growth and development.

Methods: An investigation was conducted in pot media under exposed natural conditions from August 2020 to November 2020 at Mangosuthu University of Technology. In this experiment, the growth of tomato plants were subjected to different vermicompost concentrations and amended with NPK fertilizer were studied. Sandy loam soil of about 5 kg were weighted into pot media (2.0mheight, 2.3m diameter). The experiment was set up in a completely randomized block design consisting of five treatments with five replicates per treatment. Treatments included: Positive control (PC), 5%VCL+NPK, 10% VCL+NPK, 20%VCL+NPK and the inorganic (NPK).

Result: revealed that there were significant differences at ($P<0.01$) among the treatments with respect to plant height and number of leaves from week three to week eight. Similar trends were found with 5% VCL+NPK, 10% VCL+NPK, 20% VCL+NPK and the NPK treatments. This may be due to phytohormone release from earthworm tissue. Tomato flower inflorescence was significant at ($P<0.01$). Tomato fruit, different components at harvest which were, weight wet and dry weight were higher with NPK treated at ($P<0.01$) than the 5% VCL+NPK, 10% VCL+NPK. Root length in 20% concentration was considerably higher than the other treatments. The results showed that minimum supplementation with inorganic fertiliser may be necessary with vermicompost leachate in order to successfully grow crops in nutrient deficient soil.

Key words: Growth, Organic waste, Tomato, Vermicompost.

INTRODUCTION

Feeding the increasing human population is a major challenge worldwide coupled with the devastating impact of agricultural practice on the environment (Godfray *et al.*, 2010). This suggests the need for sustainable agricultural practice to boost food production to meet the anticipated demand from the population, supermarkets and the market export board. Inorganic fertilizer is a chemical substance with mineral elements that is capable of influencing agricultural yield but may have detrimental effects. Agriculture bio-stimulants are rich in organic matter and harmless providing an alternative to the use of inorganic fertilizer (Govindapillai *et al*., 2018). Animal manure was at a time identified as a valuable source but was abandoned due to increasing cost of transportation and inappropriate timely application (Amira, 2021). The use of inorganic fertilizer is in demand to increase agricultural yield leading to an accumulation of phytochemicals in the soil causing eutrophication (Blouin *et al.*, 2019). Food quality and environmental safety in the mind of consumers across the globe is of concern. Moreover, inorganic fertilizer shortage is envisaged in the future since it is produced from non-renewable source of energy and matter (Edixhoven *et al*., 2014). The major pollution issue in the environment is linked to the increasing human population with the corresponding accumulation of waste. This may be as a result of lack of knowledge to convert these waste into a reliable form by recycling this organic waste for subsequent use as fertilizer or bio-stimulant thus reducing the use of inorganic fertilizer. Vermicompost is a bio-oxidative process whereby earthworms are used to transform organic residues into

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secondary products which are safe and more reliable to transport thereby reducing environmental risk. The use of composted material has been adopted by farmers and researchers for improving crop production. The large-scale evaluation of this compost is critically important for increasing organic matter in the soil (Dignac *et al.*, 2017). Vermicompost is produced from epigeic earthworms. Epigeic earthworms are reddish brown in colour. They are not associated with burrowing but feed on leaf litters and so provide beneficial services to the soil (Blouin *et al.*, 2013). Vermicomposting supports the reduction of organic waste ensuring stability. It has the potential to increase plant biomass and yield through its use. It increases and retains nutrient contents as well as improving the moisture level of the soil. It has hormonal effects and lowers the impact of pests and pathogens (Blouin *et al.,* 2019; Adnan *et al*., 2017). In the light of this, several studies have been devoted to studying the effect of vermicomposed materials on plant growth and soil properties (Amira, 2021) Tomato (*Solanum lycopersicum)* is largely consumed in different region of the world (Akashdeep *et al*., 2021; Papathanasiou *et al.*, 2012) and its growth can be achieved under different temperature ranges. Due to the increasing demand, this vegetable, is grown throughout the year but preferably grown in summer (Papathanasiou *et al.*, 2012). The growth and development of this crop can be influenced by various agronomic practices such as nutrient management. Nitrogen is considered an important nutrient for plant growth playing a major role in protein formation and photosynthesis of plant and growth (Zeinab *et al.*, 2014). Vermicompost improves the metabolic and physiological processes of plants. The objective of this study is to investigate the effects of various vermicompost treatments, amended with inorganic fertilizer, on tomato vegetative growth.

MATERIALS AND METHODS

This research was conducted during winter (August to November 2020) at Mangosuthu University Technology in Durban, South Africa. Vermicompost leachate was used as organic fertilizer and NPK as inorganic fertilizer. Vermicompost leachate tea extract used was prepared from *Eisenia andreii* worms + cardboard + cow dung + grass cutting (www.wizzardworm.co.za). NPK (3:1:6) as inorganic fertilizer was procured from Grovida Horticultural Store, 478 Chris Hani Road, Durban. The medium textured soil used was obtained from A-horizon of about 3 m deep from a field located at coordinates 29$^{238}_{92}$58′09″5 S 30°55′15′3 W with an altitude of 103 m. Soil used was sandy loam. Five (5) kg of thoroughly mixed soil were measured into a pot of 2.0 m with a diameter of 2.3 m using balance meter. The tomato seed variety grown was Roma VFN. Seeds were obtained from Starke Ayres (Pty) Limited Gauteng South Africa (batch number 6001363005248). Two kg of the soil was sieved through a 2 mm mesh to ascertain the various components. The average temperature during the growth period ranged between 15.73$^{238}_{92}$C minimum and 23.83$^{238}_{92}$C maximum, the humidity was about 77.25, rainfall was about 85.25 mm, average daylight recorded was 12.35 hours and the UV index was 8.5 (www.weather atlass.com/ South Africa/ Durban).

Experimental procedure and design for growth of tomato

All treatments consisted of vermicompost supplemented with NPK solution. The NPK solution was made up of 20 grams NPK + 1 litre of deionized water of which 40 ml was applied once across treatments at week three after transplanting. The treatments in the experiment were positive control (PC), 5%, 10%, 20% and NPK solution. Soil was artificially irrigated uniformly a day before seeds were sown in pots. The tomato (Roma VFN*)* seeds were sterilized in deionized water to remove any remnants of sodium hypochlorite. Seeds were soaked for 10 hrs at various concentration of VCL (0%, 5%, 10%, 20%) and NPK solution. Seeds were sown at a depth of 0.3 cm in a cup of 2 cm high with a diameter of 2 cm in which each treatment were cultured at room ambient temperature of 25±2$^{238}_{92}$C for two weeks. Seedlings at this stage had about two leaves and were transplanted two per pot. These pots were exposed to natural field conditions and sheltered from rain using transparent flexi-plastic sheeting. Treatments were applied once a week. Plants were watered twice a week with 200 ml of water.

Analysis of physical and chemical properties of the soil and vermicompost leachate

The soil collected was air dried, crushed and passed through a 1 mm-sieve at the Cedara Laboratory Unit. After dispersion and sedimentation, sand fractions, suspended clay and fine silt were determined by sieving (Day, 1965). A soil sample of about 10 g was weighed into a cup. A suspension of 25 ml of 1 M KCl was added. The mixture was stirred at 400 r.p.m for 5 min. The resultant solution was left for 30 minutes. A gel-filled combination glass electrode was used to determine the pH while stirring. Electrical conductivity of the soil (EC) was analyzed using an EC meter. Macro-Kjeldahl digestion was used to determine the total Nitrogen. This was achieved by bubble-segmented flow analysis using the colorimetric phenol-hypochlorite method (Perstorp, 1993; de Figueredo and Thurtell, 1998). ICP OES was used to determine P, K, Al, Ca, Mg, Na, Cu, Mn and Zn (Gaines and Mitchell, 1979). Similar procedures were also used to determine the nutrient present in the vermicompost.

RESULTS AND DISCUSSION

Tomato vegetative growth

Data were collected two weeks after transplanting. Data collected included plant height, number of leaves and branches. There were no significant different in the growth rate of tomato in (5, 10%) and inorganic concentrations. 20% VCL + NPK had higher value compare to the inorganic concentration (Table 1). Minimal plant height was obtained in the untreated control treatment (2.50 cm± 0.71) (Table 1). The number of leaves for all treatments had the same mean value and standard deviation a week after seedlings were acclimatized to the growth environment (Table 2). Similarly, there was no significant differences among the various

Table 1: Tomato seedlings height from week one to eight.

Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Positive control	2.50±0.71	3.40±0.548	3.80±0.274^{b**}	3.8±0.447^{b**}	5.4±0.548^{b**}	10.4±1.14^{b*}	14.9±1.67^{b**}	18.4±0.548^{b*}
5% VCL+NPK	2.80±0.27	4.40±1.084	6.10±0.894^{a**}	9±0.707^{a**}	12.4±.822^{a**}	19.3±0.975^{a*}	23.32±0.73^{a**}	27.9±3.29^{a*}
10% VCL+NPK	2.80±0.27	4.00±0.707	5.34±0.654^{a**}	8.6±1.387^{a**}	11.7±.962^{a**}	17.8±4.47^{a*}	24.34±2.110^{a**}	32.16±3.19^{a**}
20% VCL+NPK	2.60±0.42	4.50±0.500	5.04±0.559^{a*}	7.64±0.757^{a**}	10.6±.962^{a**}	19.8±0.837^{a*}	22±2.96^{a*}	28.4±4.92^{a*}
Inorganic treated	2.80±0.27	4.00±0.354	5.66±0.635^{a*}	8.08±1.176^{a**}	11.1±.302^{a**}	19.04±5.55^{a*}	24.94±4.55^{a**}	32.86±4.02^{a**}

**Means ($P<0.001$) *($P<0.005$) mean±SD.

Plants were subjected to various treatments (PC, 5, 10, 20% VCL+NPK and NPK).

Table 2: Number of tomato leaves from week one to week eight.

Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Positive control	2.0±0	3.0±0.0	3.20±0.45^{b}	4±0.00^{b*}	12.6±.548^{b**}	13.8±1.48^{b*}	16.6±1.14^{b*}	20.6±0.89^{b**}
5% VCL+NPK	2.0±0	4.0±0.0	4.00±0.00^{a*}	6.2±0.84^{a*}	22.8±0,84^{b**}	34.8±5.59^{a*}	50.2±12.36^{a*}	68.8±15.66^{a**}
10% VCL+NPK	2.0±0	4±0.0	3.80±0.45^{ab}	6.6±0.90^{a**}	26.4±.362^{b**}	42.6±5.18^{a**}	61.8±8.96^{a*}	78.6±14.01^{a**}
20% VCL+NPK	2.0±0	4±0.0	3.80±0.45^{ab}	6±1.0^{a*}	21.8±3.39^{b*}	36.8±8.79^{a**}	55.4±14.35^{a**}	71±19.27^{a**}
Inorganic treated	2.0±0	4±0.0	4.00 ±0.00^{a}	6.6±0.90^{a**}	22.6±6.11^{b*}	43.6±12.84^{a**}	66.8±18.02^{a}	89.2±18.83^{a**}

Plants were subjected to various concentrations (PC, 5, 10, 20% VCL+NPK and NPK).

Table 3: Number of tomato leaves from week one to week eight.

Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Positive control	2.0±0	3.0±0.0	3.20±0.45^{b}	4±0.00^{b*}	12.6±.548^{b**}	13.8±1.48^{b*}	16.6±1.14^{b*}	20.6±0.89^{b**}
5% VCL+NPK	2.0±0	4.0±0.0	4.00±0.00^{a*}	6.2±0.84^{a*}	22.8±0,84^{b**}	34.8±5.59^{a*}	50.2±12.36^{a*}	68.8±15.66^{a**}
10% VCL+NPK	2.0±0	4±0.0	3.80±0.45^{ab}	6.6±0.90^{a**}	26.4±.362^{b**}	42.6±5.18^{a**}	61.8±8.96^{a*}	78.6±14.01^{a**}
20% VCL+NPK	2.0±0	4±0.0	3.80±0.45^{ab}	6±1.0^{a*}	21.8±3.39^{b*}	36.8±8.79^{a**}	55.4±14.35^{a**}	71±19.27^{a**}
Inorganic treated	2.0±0	4±0.0	4.00 ±0.00^{a}	6.6±0.90^{a**}	22.6±6.11^{b*}	43.6±12.84^{a**}	66.8±18.02^{a}	89.2±18.83^{a**}

Plant were subjected to various concentrations (PC, 5, 10, 20% VCL+NPK and NPK).

parameters tested (Table 2). There were no significant differences recorded in plant height of tomato in 5% VCL + NPK, 10% VCL + NPK and the NPK treatments after 7 days. However, a significant difference in plant height was noted in the 20% treatment (Table 1). After 21 days, 5% VCL + NPK gave the highest plant height readings (6.10±0.894) followed by the PC treatment (Table 1). The number of leaves were higher in the 5% VC + NPK and inorganic treatments with the PC treatment showing the least number (3.20±0.447) (Table 2). At day 28 of growth, the inorganic treatment produced the tallest plants (8.08±1.176) (Table 1) compared to the other treatments at day 35 days of growth that the 5% VCL + NPK (12.4±0.822) treatment indicated greater number of leaves compared to the rest of the treatments. A similar trend was observed for the rest of the variables tested. All the results obtained with the VCL + NPK treatment was consistently higher than the PC treatment. After 56 days, the inorganic treatment (32.86±4.02) produced the best results (Table 1). The analysis of variance indicated that there were significant differences among treatments with respect to plant height and number of leaves from week three to week eight at (P<0.01) (Table 1 and 2). Tomato branches across treatments were also significantly different after week six (Table 3). It appeared that the inorganic treatment produced the best overall result.

Wet and dry weight with respect to treatments

Tomato plant were harvested from the growth media. Plant was carefully risen with tap water to remove soil from the plant. Moisture was allowed to dry off before weighing. The wet weight of the leaves, shoot and root were assessed using weigh balance. The wet weight of leaves were significant at (P<0.01) (Table 4). No significant difference was observed in wet weight of the leaf of tomato in (5, 10 and 20%) concentrations. However, a significant difference was obtained in the wet weight of tomato in NPK concentration. The wet weight of tomato shoot recorded a higher value compared to the (5, 10, 20%) concentrations. Likewise, it was found that NPK treatment had the highest value with tomato wet root. Moreover, the result obtained with (5, 10 and 20%) concentrations in wet weight of root were lower compared to the NPK treatment. The dry weight of tomato biomass were assessed from the various treatments. Plant biomass was oven dried at 60°C for 48 hours. The result obtained revealed that the dry weight of leaves was significant at (P<0.01) (Table 5). The dry weight of leaf of tomato were not significant in (5, 10, 20%) concentrations but was significant in NPK treatment. In the same vein, the dry weight of shoot of tomato was significantly higher with NPK treatment compared to the (5, 10 and 20%) concentrations. The dry weight of root obtained in (5, 10 and 20%) concentrations were lower compared to the NPK treatment (Table 5). The NPK treatment had the highest value. However, the wet and dry weight of tomato in (5, 10 and 20%) concentration were significantly higher than the untreated control (Table 5).

Number of fruits with respect to treatments

The development of flowers into fruits was noted at about 80 day after germination (Table 6). The number of tomato fruit obtained with (5, 10, 20%) concentrations were not significant compared to the number of tomato fruit obtained in NPK concentration. At week eleven, it was observed that there were no significant difference in the number of tomato fruit in (5, 10, 20%) (Table 6). Though, a significant difference was observed in NPK treatment. The number of tomato fruit found with (5, 10 and 20%) were higher compared to the untreated control (Table 6)

Fourty mL of inorganic fertilizer was added to each of the vermicompost concentrations to reduce excess nitrate

Table 4: Wet weight of tomato plants.

Treatments	Weight of leaves	Wet weight of shoot	Wet weight of root
Positive control	2.62±1.43^{c**}	10.62±3.15^{b**}	4.36±3.57^{b*}
5% VCL+NPK	8.19±3.80^{bc**}	21.2±6.94^{b**}	10.45±3.45^{ab*}
10% VCL+NPK	11.29±6.72^{bc**}	21.1±9.88^{b**}	13.66±3.45^{ab*}
20% VCL+NPK	12.76±3.42^{b**}	22.65±4.35^{b**}	11.29±5.44^{ab*}
Inorganic treated	23.79±5.87^{a**}	42.99±9.44^{a**}	18.95±6.84^{a*}

** means (P<0.001) *(P<0.005) mean±SD.

Plant were subjected to various concentrations (PC, 5, 10, 20% VCL+NPK and NPK).

Table 5: Dry weight of tomato plants.

Treatments	Dry weight of leaves	Dry weight of shoot	Dry weight of root
Positive control	0.67±0.274^{c**}	2.13±1.15^{b**}	1.63±0.68
5% VCL+NPK	1.67±0.477^{bc**}	2.63±1.04^{b**}	2.002±0.952
10% VCL+NPK	1.75±1.16^{bc**}	3.44±1.63^{b**}	1.734±0.71
20% VCL+NPK	2.23±0.629^{b**}	4.16±0.623^{b**}	3.122±2.63
Inorganic treated	4.52±1.54^{a**}	7.24±1.69^{a**}	4.45±2.496

** means (P<0.001) * (P<0.005) mean±SD.

Plant were subjected to various concentrations (PC, 5, 10, 20% VCL+NPK and NPK).

Table 6: Number of tomato fruit.

Treatments	Week 10	Week 11
Positive control	0.4±0.548^{c**}	0.4±0.548^{c**}
5% VC+NPK	1.4±1.34^{b**}	2.6±1.14^{b**}
10% VCL+NPK	2±0.0^{b**}	2.4±0.548^{b**}
20% VCL+NPK	2.4±1.52^{ab**}	4.2±1.92^{ab**}
Inorganic treated	4±2.65^{a**}	5±1.87^{a**}

** Means (P<0.01) * (P<0.05) mean±SD.

Plant were subjected to various concentrations (PC, 5, 10, 20% VCL+NPK and NPK).

which may possibly be stored in the fruit and in the soil at harvest. A better yield could be related to behavior of the plant at the two week stages after planting. This behavior is associated with the amount of nutrients in the present in the soil. In this case, efficient growth and development might be influenced by the slow release of NPK from the organic manure into the soil (Reshid *et al.*, 2014). Moreover, the release of these elements from the organic manure depends largely on the original feedstock, processing time and maturity (Akashdeep *et al.*, 2021; Campitelli andCeppi, 2008). Nutrients are required by most hybrid varieties and may result in plant nutrient deficiencies. Soil with adequate nutrient elements may create a balance with the available NPK and release nutrients from the organic compound (Khan *et al.,* 2017). More so, the insignificant difference with respect to plant height and number of leaves in the first two weeks may be due to poor soil structure and the slow release of NPK into the soil (Khan *et al.*, 2017). The application of vermicompost increases actinomycetes and microbial population of N_2 fixation. This is achieved through degradation of earthworm and mineralization of organic waste. Phosphorus and nitrogen are also induced through microbial activities (Campitelli and Ceppi, 2008). This plays a significant role in the photosynthetic function of the plant. However, ecofriendly humus like organic substance is developed through aerobic and biological methods (Papathanasiou *et al.*, 2012). This is associated with a balance in organic and inorganic nutrients, moisture and optimum temperature. This is significant to health and physiochemical properties of the soil (Khan *et al.*, 2017). Tomato grown under hydroponics condition with a combination of organic and inorganic compounds had the highest vegetative growth. The result obtained with 5% VCL + NPK, 10% VCL + NPK and 20% VCL + NPK treatments from week three to week eight showed a significant improvement in height, number of leaves and branches compared to the control (Rodriguez *et al.*, 2015).

CONCLUSION

The study showed that the inorganic treatment produced the highest flower inflorescence, number of tomato fruit, wet and dry weight compared to the other treatments. Differences between treatments may be due to the type of worms used during composting, the process involved and or the time of maturity. It is possible that there was insufficient release of micro and macronutrient in the soil to address soil deficiency. A similar trend observed with VCL + NPK concentrations and inorganic fertilizer may indicate that the excessive use of inorganic fertilizer can be reduced. This is to minimize cost of production. The 20% VCL + NPK treatment was significantly higher than the 5% VCL + NPK and 10% VCL + NPK treatments. This indicated that a higher vermicompost concentration may be required to make up for plant growth and soil deficiency. Likewise, it is necessary that a dose of inorganic fertilizer is required to combine with the vermicompost to prevent unnecessary accumulation of nitrate in the tomato fruit and soil.

RECOMMENDATIONS

The feedstock and the type of worms used during vermicomposting are of paramount importance. Similarly, the time for processing vermicompost and maturity plays a significant role in the release of micro and macronutrient in the soil. Further research can be carried out to find the minimum organic fertilizer that sufficiently boost production. Since higher concentrations of vermicompost was found to be more effective at increasing growth and tomato yield. It is recommended that organic fertilizer must be supplemented with minimal quantity of NPK. The use of vermicompost alone may not sufficiently boost food production. It is essential to minimize the use of inorganic fertilizer to boost food production in a safe and sustainable manner.

Conflict of interest: None.

REFERENCES

Adnan, A.K., Hamida, B.Z.A., Muhammad, S., Syed, A.S., Haroon, I., Kashif, K., Imran, A., Sajid, A. (2017). Effect of organic manures and inorganic fertilizers on plant growth, yield, fruit quality of tomato (*Solanum lycopersicon* L.). Academic Journal of Agricultural Research. 5(10): 287-293.

Amira. A.H. (2021). Enhancing the productivity and quality of tomato using magnetized water and humic acid as bio stimulant agents. Indian Journal of Agricultural Research. (55): 645-655.

Akashdeep, S., Pawan, P., Tarun, S., Sanjay, S. (2021). Effect of different crop sequences on soil nutrient status, nutrient uptake and crop yield in Western Himalayas of India. Indian Journal of Agricultural research. (55): 733-738.

Blouin, M., Julien, B., Nicolas, M., Silène, L., Sébastien, B., Jérôme, M. (2019). Vermicompost significantly affects plant growth. A meta-analysis. Nature Agronomy for Sustainable Development. 39(4): 1-15.

Blouin, M., Hodson, M.E., Delgado, E.A. (2013). A review of earthworm impact on soil function and ecosystem services. European Journal Soil Science. 64: 161-182.

Campitelli, P., Ceppi, S. (2008). Chemical, physical and biological compost and vermicompost characterization: A chemometric study. Chemometrics and Intelligent Laboratory System. 90: 64-71.

De Figueiredo, M. and Thurtell, L. (1998). Analytical methods and instruments used in the Cedara Feed Laboratory. Cedara Report No. N/A/98/13. KwaZulu-Natal Department of Agriculture.

Day (1965). Particle Fractionation and Particle-size Analysis. In: C.A. Black *et al.* (eds) Methods of Soil Analysis, Part 2. Agronomy. 9: 1367-1378.

Dignac, M.F., Derrien, D., Barré, P. (2017). A review: Increasing soil carbon storage: mechanisms, effects of agricultural practices and proxies. Agronomy Sustainable Development. 37: 14. https://doi.org/10.1007/s13593- 017-0421-2.

Edixhoven, J.D., Gupta, J., Savenije, H.H.G. (2014). Recent revisions of phosphate rock reserves and resources: Reassuring or misleading? An indepth literature review of global estimates of phosphate rock reserves and resources. Earth System Dynastic. 5: 491-507.

Gaines, T.P., Mitchell. G.A (1979). Boron determination in plant tissue by the azomethine H method. Communications in Soil Science and Plant Analysis. 10: 1099-1108.

Govindapillai, S., Rekha, A., Kunyil, K., Devan, E., Mundarath, P., Srikumaran, V., Namasivayam, M. (2018). Effects of vermicompost and plant growth enhancers on the exo morphological features of *Capsicum annum* (Linn.) Hepper. International Journal of Recycling of Organic Waste in Agriculture. 7: 83-88.

Godfray, H.C.J., Beddington, J.R., Crute, I.R. (2010). Food security: The challenge of feeding 9 billion people. Science Journal. 327: 812. https://doi. org/10.4337/9780857939388.

Khan, A.A., Bibi, Z., Ali, Z., Sharif, M. (2017). Effect of compost and inorganic fertilizers on yield and quality of tomato. Academia Journal of Agricultural Research. 5(10): 287-293, DOI: 10.15413/ajar.2017.0135 ISSN: 2315-7739.

Perstorp Analytical (1993). Total Kjeldahl nitrogen. Environmental Methodology Documentation. 000579, Rev. C. Perstorp Analytical.

Papathanasiou, F., Ioannis, P., Ioannis, T., Efstathios, T. (2012). Vermicompost as a soil supplement to improve growth, yield and quality of lettuce (*Lactuca sativa* L.). Journal of Food Agriculture and Environment. 10(2): 677-682.

Reshid, A., Tesfaye, S., Tesfu, K. (2014). Effects of different rates of vermicompost as potting media on growth and yield of tomato (*Solanum lycopersicum* L.) and soil fertility enhancement soil and water research process. Sky Journal of Soil Science and Environmental Management. 3(7): 073-077.

Rodríguez, S.F., Meléndez, E.J., Ulloa, R.M., Maribel, Q.C. (2015). Degradation of sewage sludge from plant wastewater using vermicompost. International Journal of Modern Biology Research. 4: 1-4 ISSN 2053-180X.

Zeinab, A.B., Masoud, H.Z.R. (2014). Effect of vermicompost and chemical fertilizers on growth parameters of three corn cultivars. Journal of Applied Science and Agricultural. 9(9): 22-2.