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Pooja
Department of Agriculture, MM (DU), Mullana, Ambala, Haryana, India

MK Rana
Department of Agriculture, MM (DU), Mullana, Ambala, Haryana, India

Amandeep Sharma
Department of Agriculture, MM (DU), Mullana, Ambala, Haryana, India

OP Mehla
Department of Agriculture, MM (DU), Mullana, Ambala, Haryana, India

Devi Singh
Department of Agriculture, MM (DU), Mullana, Ambala, Haryana, India

Abhishek Singh
Scientist B, MESSO, Central Silk Board, NONGPOH, Meghalaya, India

Sudhanshu Verma
Research Scholar, Department of Agronomy, Institute of Agricultural Sciences, BHU, Varanasi, Uttar Pradesh, India

Corresponding Author:
Pooja
Department of Agriculture, MM (DU), Mullana, Ambala, Haryana, India

Vermicompost effect on soil and field crops: A review

Pooja, MK Rana, Amandeep Sharma, OP Mehla, Devi Singh, Abhishek Singh and Sudhanshu Verma

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Abstract
Vermicompost is a secondary product resulting from the degradation of agricultural wastes by earthworms. Under favourable conditions, earthworms ingested agricultural wastes and decrease the volume by 40-60%. Vermicompost is rich in nitrogen, phosphorus, potassium, micronutrients, vitamins, growth hormones and enzymes such as protease, amylase, lipase, cellulase, chitinase, etc. Vermicomposting is a process, in which, earthworms are used to convert organic materials (usually organic wastes) into humus like material, which after incorporation improves physical, chemical and biological properties of the soil, carbon to nitrogen ration and also acts as a soil conditioner. Since vermicompost is rich in macro- and micro-nutrients as well as in hormones, it increases the rate of seed germination and growth and development of seedlings.

Keywords: Vermicompost, nutrients, enzymes, hormones, secondary products

Introduction
With the advancement in agriculture, the use of natural supplements for increasing the crop yield and quality is neglected by the farmers, which results in the reduction of soil fertility and quantity and quality of crop. Instead of using manures, excess use of chemical fertilizers is not only affecting the economy of the country but also affecting the quality of produce adversely. Lots of natural nutrients (plant- and animal-based) have been derived from different sources to maintain the quantity and quality of the crops. Among these, vermicompost is one of the most common and nutrients rich manure. Vermicomposting is a process, in which, certain species of earthworms, like *Eisenia fetida* and *Eisenia andrei*, are used to initiate the process of organic waste conversion into a better end-product. Vermicompost plays a major role in improving growth and yield of different cereal, pulse, fruit, vegetable and flower crops. Vermicompost shows a positive effect on vegetative growth, stimulating root and shoot growth (Edwards *et al.*, 2004) [23] as well as it contains highly organic carbon and useful plant nutrients (Edwards and Bohlen, 1996 [21]. Use of vermicompost is the most efficient way to protect natural resources, both environmentally and economically. It is estimated that the annual amount of organic waste in the world is about 1.3 billion tonnes, which is expected to reach 2.2 billion tonnes per year by 2025 (Singh and Singh, 2017) [57].

Nutrient content in vermicompost
Vermicompost contains high percentage of both macro- and micro-nutrients, which are readily available to the plants within a month of application (Sreenivas *et al.*, 2000) [62]. Vermicompost is a manure that contains all essential plant nutrients like nitrogen (1.94%), phosphorus (0.47%), potassium (0.70%), magnesium (0.46%), iron (7563 ppm), zinc (278 ppm), manganese (475 ppm), boron (34 ppm) and cupper (27 ppm), thus, it eliminates the usage of any further synthetic chemical in soil (Ceritoglu *et al.*, 2019) [10]. Further, the nutrients in vermicompost are often much higher than traditional garden compost (Alam *et al.*, 2007) [2].

Physical, chemical and biological property of vermicompost
Vermicompost have many remarkable biological properties due to the presence of beneficial actinomycetes, fungi and cellulose-degrading bacteria (Edwards, 1983 [20]; Tomati *et al.*, 1987 [67]; Werner and Cuevas, 1996) [70] and increase microbial biomass and phosphatase enzyme activity in soil. It enhances the microbial activity in soil, regulates soil temperature, improves soil porosity and water retention capacity, increases oxygen availability (Arora *et al.*, 2011) [4], helps in improving plant growth and suppressing pathogens' attack (Pathma and Sakthivel, 2013) [46] and other physico-chemical properties of the soil.

(Sinha *et al*., 2009) [61] Vermicompost is rich in antioxidants, vitamins, humic acid, phenolic substances and various hormones (Joseph, 2019) [31].

During ingestion, the earthworms accelerate the rate of organic matter decomposition and alter the physical and chemical properties of the material, leading to an effect similar to composting, in which, the unstable organic matter is oxidized and stabilized aerobically (Atiyeh, 2000) [6]. Vermicompost converted into peat-like material improves porosity, aeration, drainage and water-holding capacity of the soil (Edwards and Burrows, 1988) [22].

Vermicompost is a rich source of efficient antagonistic bacteria aiding in suppression of diseases caused by devastating soil-borne phyto-pathogenic fungi (Chaoui *et al*., 2002 [14]; Singh *et al*., 2008 [59]; Pathma and Sakthivel, 2012) [45].

Effect of vermicompost on growth of crop

Vermicompost helps in promoting root initiation, root biomass and plant growth. Nagavallemma *et al*. (2004) [42] reported higher germination (93%), growth and yield of mung bean with the application of vermicompost. Vermicompost contains remarkable nutrients, beneficial micro-organisms, plant hormones like gibberellins, auxin, cytokinin and B group vitamins that help the plants to give better yield (Tomati *et al*., 1983 [66]; Bano *et al*., 1987 [8]; Bhawalker, 1991) [9]. Das *et al*. (2002) [15] found that dry matter content, pod yield, plant height, nutrients uptake, root volume and number and weight of nodules were higher when the vermicompost was applied @ 3 kg per pot. Channabasanagowda *et al.* (2008) [11] reported that plant height (86.3 cm) and number of tillers per plant (94.6) at 90 DAS, number of earheads m^{-2} (160.1), test weight (42.73 g), protein content (13.41%) and grain yield (3043 kg/ha) were significantly higher in crop harvested from the plot supplied with vermicompost @ 3.8 t/ha + poultry manure @ 2.45 t/ha. Bajracharya and Rai (2009) [7] found that the application of vermicompost @ 5 kg per pot significantly increased the plant height, root length and dry weight of chickpea. In green gram, Ghanshyam and Jat (2010) [24] observed that the crop with the application of vermicompost and farmyard manure each @ 5 t/ha had the maximum number of root nodules per plant at 40 DAS, plant height, pods per plant and test weight as compared to control. Mycin *et al.* (2010) [41] concluded that the growth parameters like root and shoot length, number of leaves per plant, fresh weight, dry weight and root nodules, yield parameters and the content of nutrients *viz*., nitrogen, phosphorus and potassium were more under the treatment vermicompost @ 4 t/ha in groundnut crop. Devi *et al.* (2013) [19] reported that the combination of 75% RDF (40: 60: 20 kg/ha) with vermicompost @ 1 t/ha and Phosphate Solubilizing Bacteria resulted in significantly taller plants (41.49 cm), more number of nodules per plant (43) and dry weight of nodules per plant (149.13 mg) in soybean crop. Rana and Badaliya (2014) [51] found that the soybean crop supplied with farmyard manure @ 2.5 t/ha + vermicompost @ 1.25 t/ha had significantly taller plants (76 cm) and more dry matter accumulation (509 g m^{-2}). Chaudhary *et al.* (2015) [13] concluded that with the application of 125% recommended dose of nitrogen through vermicompost, the groundnut crop gave higher pod yield (2650 kg/ha), haulm yield (4633 kg/ha), growth and yield parameters, *viz*. plant height (43.9 cm), filled pods per plant (22.6), total pods per plant (31.4), pod weight per plant (22.3 g) and 100 kernels weight (43.9 g), net return and benefit to cost ratio due to its better plant growth. Application of vermicompost either alone or in combination with organic or chemical fertilizers has been proved effective to enhance growth and yield of various plants like Urd and Soya bean (Javed and Panwar, 2013) [30]. The incorporation of vermicompost-derived humic acids into soilless plant growth media increased the growth of tomato and cucumber plants significantly in terms of plant height, leaf area, shoot and root dry weight (Atiyeh *et al*., 2002) [6]. These growth responses were most probably due to the hormone-like activity of humic acids from the vermicompost, which could have been due to plant growth hormones adsorbed onto the humates.

Effect of vermicompost on development of crop

Jayaprakash *et al*. (2003) [27] reported that the maize crop supplied with vermicompost @ 2 t/ha gave higher grain yield (67.47 q/ha), which was at par with the application of farmyard manure @ 10 t/ha (65.22 q/ha). Jat and Ahlawat (2004) reported that the application of vermicompost @ 3 t/ha resulted in significantly higher plant dry matter, leaf area, pods per plant and seed and straw yield in chickpea. Vasanthi and Subramanian (2004) recorded the maximum protein, nitrogen, phosphorus and potassium uptake when the crop received vermicompost @ 2 t/ha along with 100% RDF. Singh and Prasad (2007) [57] revealed that the application of vermicompost @ 2 t/ha resulted in the production of higher dry matter (35.57 g per plant), seed weight per plant (14.05 g) and straw (22.99 q/ha) and seed (19.09 q/ha) yield in chickpea as compared to control. Sweet sorghum with the application of vermicompost @ 2.5 t/ha along with seed treatment of *Azospirillum* and PSB gave significantly more green-cane, juice and grain yield (Kagne *et al*., 2008) [32]. Randhe *et al.* (2009) [52] concluded that the application of 125% nitrogen through vermicompost (16.48 t/ha) + *Azotobacter* + PSB resulted in higher straw and grain yield and protein content in wheat. Paliwal *et al*. (2011) [43] reported that the application of vermicompost @ 5 t/ha + 25% reduction in RDF resulted in significantly more number of pods per plant (43.5), number of seeds per pod (2.8), test weight (11.5 g) and seed yield (25.4 q/ha) in soybean. Patra *et al.* (2011) found that the groundnut crop receiving vermicompost @ 2.5 t/ha + phosphocompost @ 2.5 t/ha + poultry manure @ 2.5 t/ha + neem cake @ 2.5 t/ha showed more uptake of nutrients (nitrogen, phosphorus and potassium) as compared to 100% RDF and control. Davari *et al.* (2012) [18] observed that the application of vermicompost in wheat resulted in a significant increase in all growth and yield parameters, which led to 28.9-76.1% increase in grain yield and 25-70% in straw yield over control. Vasoya (2014) [69] found that fennel performed better in terms of yield attributes, *viz*. number of umbels per plant, umbellates per umbel, seeds per umbel and test weight when the crop was supplied with castor cake @ 1.0 t/ha and vermicompost @ 1.5 t/ha. Application of vermicompost @ 2, 4 and 6 t/ha consistently and significantly increased seed and Stover yield, protein content, oil content and net return in mustard crop (Kansotia *et al*., 2015) [33]. Khan *et al.* (2017) [63] reported that the crop with the application of vermicompost @ 6 t/ha gave significantly higher number of pods per plant and number of seeds per pod than the crop under control. The application of vermicompost significantly increased the yield of cucumber (Zhao *et al*., 2017) [71]. The application of vermicompost @ 125% + *Rhizobium* + PGPR) treated plots produced significantly more dry weight per plant (5.7 g), number of pods per plant (58.7), number of seeds per pod (1.7), test weight (19.2 g), seed Yield (2520 kg/ha) and harvest index (33.4). The application of vermicompost (VC 100%) positively affected plant height (cm), number of branches and chlorophyll content except number of pods (Mahmoud and Gad, 2020). With the increase in vermicompost level nitrogen, protein, carbohydrate and phosphorus contents increased to 40.21, 40.17, 47.39 and 12.49% respectively (Shrimal and Khan, 2017) [63]. The treatment 50% vermicompost + 50% NPK supplies higher macro- and micro-nutrients to the soil and plants in the available from which results in better growth, yield and quality of beans (Manivannan *et al*. 2009) [39]. Pea crop gave maximum yield when vermicompost was applied in soil @ 10 t/ha along with recommended dose of N, P and K (Reddy *et al*., 1998) [53]. Phosphorus-enriched vermicompost is reported to have beneficial effects on yield of groundnut crop (Das *et al*., 2015) [16].

Effect of vermicompost on soil properties

Application of vermicompost can increase nitrogen in the soil by 42%, phosphorus by 29% and potassium by 57%. Vermicompost is known for improving physical properties of soil such as aggregate formation, bulk density, porosity and electric conductivity due to the action of humic acid on soil structure (Hanc and Vasak, 2015) [26]. Earthworm secretes gelatinous substance that makes a thin coat on soil particles, making the soil mineral stabilized. Earthworm casts are usually more water stable than natural aggregates of soil. Sharma and Agrawal (2003) [55] observed that the application of vermicompost @ 7.5 t/ha increased the soil fertility by improving the content of organic carbon (0.39%) and available nitrogen (219 kg/ha) in soil after harvesting of forage sorghum. Kumar *et al*. (2005) [36] observed maximum residue build-up of organic carbon and available nitrogen, phosphorus and potassium in the soil with the application of vermicompost (5 t/ha) followed by farmyard manure (5 t/ha) and inorganic fertilizers (nitrogen @ 40 kg/ha + phosphorus @ 20 kg/ha). Jat and Ahlawat (2006) [29] reported that applying vermicompost @ 3 t/ha in chickpea crop increased dry matter accumulation, grain yield and protein content in chickpea, nitrogen and phosphorus content and bacterial count in soil, dry fodder yield of succeeding maize and total nitrogen and phosphorus uptake by the cropping system over control. Suhane (2007) observed that the exchangeable potassium in vermicompost was more than 95%. Vermicompost is at least 4 times more rich in nutrients, especially in calcium, magnesium, zinc and manganese, than cattle dung compost. The physical properties such as water holding capacity, moisture content and porosity were improved when soil was amended with vermicompost. Among the treated group, the crop growth rate was higher in the mixture of vermicompost and vermiwash treated plants than the vermicompost and vermiwash untreated plants (Tharmaraj *et al.*, 2011) [65]. Chaitnya *et al.* (2013) [12] recorded the maximum activity of dehydrogenase, acid phosphatase and alkaline phosphatase with the application of 50% vermicompost and 50% poultry manure. Mathivanan *et al.* (2013) [40] reported that the soil properties such as pH, EC, available nitrogen, phosphorus, potassium, iron, zinc, copper and manganese were found more in vermicompost treated pot. In garlic crop, Patil (2013) [47] recorded the maximum water stable aggregate of >1.0 mm size and the lowest bulk density with 100% nitrogen through equal concentration of vermicompost, bio-compost and castor cake + banana pseudostem sap @ 2000 litre per hectare. Vermicompost increases the micropores, allowing more nutrients to be retained. Nagavallemma *et al.* (2004) [42] reported that vermicompost application significantly improved the soil chemical properties such as pH, electrical conductivity, organic matter and nutrient status and resulted in better plant growth and yield (Lim *et al*., 2015) [37]. Vermicompost reduces the concentration of heavy metals in the applied soil.

Conclusion

Vermicompost can increase growth and yield of the crops. In general, application of vermicompost at low rate, *i.e.*, 2-5 t/ha can significantly improve growth, yield and quality of the crops in field. The effect of vermicompost on plants and soil is not solely attributed to the quality of mineral nutrition but also to its other growth regulating components such as plant growth hormones and macro- and micro-nutrients. Furthermore, the application of vermicompost in the field improves the quality of soil by increasing microbial biomass and microbial activity, which are important components in cycling of nutrients, production of plant growth regulators and protecting the plants from soil-borne diseases and insect-pests.

References

1. Alam MM, Ladha JK, Khan SR, Foyjunnessa, Harun-ur-Rashid, Khan AH, Buresh RJ. Leaf color chart for managing nitrogen fertilizer in lowland rice in Bangladesh. Agron. J. 2005;97:949-959.
2. Alam MN, Jahan MS, Ali MK, Ashraf MA, Islam MK. Effect of vermicompost and chemical fertilizers on growth, yield and yield components of potato in barind soils of Bangladesh. J. Appl. Sci. Res. 2007;3(12):1879-1888.
3. Ali U, Sajid N, Khalid A, Riaz L, Rabbani MM, Syed JH, *et al*. A review on vermicomposting of organic wastes. Environ. Prog. Sustain. Energy. 2015;34(4):1050-1062.
4. Arora VK, Singh CB, Sidhu AS, Thind SS. Irrigation, tillage and mulching effects on soybean yield and water productivity in relation to soil texture. Agri. Water Mgt. 2011;98(4):563-568.
5. Atiyeh R, Lee S, Edwards C, Arancon Q, Metzger J. The influence of humic acids derived from earthworm processed organic wastes on plant growth. Bioresour. Tech. 2002;84(1):7-14.
6. Atiyeh RM, Arancon NQ, Edwards CA, Metzger JD. Influence of earthworm-processed pig manure on the growth and yield of greenhouse tomatoes. Bioresour. Technol. 2000;75:175-180.
7. Bajracharya SK, Rai SK. Study on the effects of vermicompost on nodulation and yield of chickpea. Nepal Agri. Res. 2009;9:49-55.
8. Bano B, Kale RD, Gajanan GN. Culturing of earthworm (*Eudrilus engeniae*) for cast production and assessment of wormcast as bio-fertilizer. J Soil Biol. Ecol. 1987;7:98-104.
9. Bhawalker US. Vermiculture Biotechnology for LEISA. In: Seminar on Low External Input Sustainable Agriculture, Amsterdam, The Netherlands; c1991. p. 1-6.
10. Ceritoglu M, Şahin S, Erman M. Vermikompost üretim

tekniği ve üretimde kullanılan materyaller. Türkiye Tarımsal Araştırmalar Dergisi. 2019;6(2):230-236.
11. Channabasanagowda B, Patil NK, Patil BN, Awaknavar JS, Ninganur BT, Hunge R. Effect of different organic manures on growth, seed yield and quality of wheat. Karnataka J. agric. Sci. 2008;21(3):366-368.
12. Chaitnya T, Padmaja G, Rao P, Chandrashekhar. Activity of soil urease, dehydrogenase and phosphatase as influenced by integrated nutrient management in tomato (*Lycopersicon esculentum* L.) grown on alfisol. Crop Res. 2013;45(1-3):210-214.
13. Chaudhary JH, Sutaliya R, Desai LJ. Growth, yield, yield attributes and economics of summer groundnut (*Arachis hypogaea* L.) as influenced by integrated nutrient management. J. Appl. Natl. Sci. 2015;7(1):369-372.
14. Chaoui H, Edwards CA, Brickner M, Lee S, Arancon N. Suppression of the plant diseases, Pythium (damping off), Rhizoctonia (root rot) and Verticillum (wilt) by vermicompost. In: Proceedings of Brighton Crop Protection Conference-Pests and Diseases, Croydon, England. 2002;2(8B-3):711-716.
15. Das PK, Sarangi D, Jena MK, Mohanty S. Response of green gram (*Vigna radiata* L.) to integrated application of vermicompost and chemical fertilizer in acid lateritic soil. Indian Agristatistics. 2002;46(1 & 2):79-87.
16. Das T, Debnath SB, Satpute SB, Bandyopadhyay S. Effect of phosphorus enriched vermicompost on growth and yield of groundnut (*Arachis hypogaea* L.) as influenced by soil phosphorus use efficiency. Indian J. and Tech. 2015;8(11):1-11.
17. Domínguez J, Edwards CA. Relationships between composting and vermicomposting: relative values of the products. In: Vermiculture Technology: Earthworms, Organic Waste and Environmental Management (Eds. Edwards CA, Arancon NQ and Sherma RL). CRC Press. Boca Raton, Florida; c2011. p. 1-14.
18. Davari MR, Sharma SN, Mirza KM. The effect of combinations of organic materials and biofertilizers on productivity, grain quality, nutrient uptake and economics in organic farming of wheat. J. Org. Sys. 2012;7(2):26-35.
19. Devi KN, Singh TB, Athokpam SH, Singh NB, Shamurailatpam D. Influence of inorganic, biological and organic manures on nodulation and yield of soybean (*Glycine max* L.) and soil properties. Aust. J Crop Sci. 2013;7(9):1407-1415.
20. Edwards CA. Utilization of earthworm composts as plant growth media. In: International Symposium on Agricultural and Environmental Prospects in Earthworm (Eds. Tomati, U. and Grappelli, A.). Rome, Italy; c1983. p. 57-62.
21. Edwards CA, Bohlen PJ. Biology of earthworms. In: Biology and Ecology of Earthworms, 3rd edn. (Eds. Edwards, C.A. and Bohlen, P.J.). Chapman & Hall, London, UK; c1996. p. 426.
22. Edwards CA, Burrows I. The potential of earthworms composts as plant growth media. In: Earthworms in Waste and Environmental Management (Eds. Edward, C.A. and Neuhauser, E.F.). SPB Academic Publishing, The Hague, The Netherlands; c1988. p. 21-32.
23. Edwards CA, Domínguez J, Arancon NQ. The influence of vermicomposts on plant growth and pest incidence. In: Soil Zoology for Sustainable Development in the 21st Century (Eds. Shakir, S.H. and Mikhaïl, W.Z.A.), Cairo; c2004. p. 397-420.
24. Ghanshyam RK, Jat RK. Productivity and soil fertility as effected by organic manures and inorganic fertilizers in green gram (*Vigna radiata*)-wheat (*Triticum aestivum*) system. J. Agron. 2010;55(1):16-21.
25. Grapelli A, Tomati U, Galli E, Vergari B. Earthworm casting in plant propagation. Horti. Sci. 1985;20:874-876.
26. Hanc A, Vasak F. Processing separated digestate by vermicomposting technology using earthworms of the genus Eisenia. Int. J Environ. Sci. Tech. 2015;12:1183-1190.
27. Jayaprakash TC, Nagalikar VP, Pujari BT, Setty RA. Effect of organics and inorganics on yield and yield attributes of maize under irrigation. Karnataka J. Agri. Sci. 2003;16(3):451-453.
28. Jat RS, Ahlawat IPS. Effect of vermicompost biofertilizer and phosphorus on growth, yield and nutrient uptake by gram (*Cicer arientinum*) and their residual effect on fodder maize (*Zea mays*). Indian J agric Sci. 2004;74(7):359-361.
29. Jat RS, Ahlawat IPS. Direct and residual effect of vermicompost, biofertilizers and phosphorus on soil nutrient dynamics and productivity of chickpea-fodder Maize sequence. J Sust. Agri. 2006;28(1):41-54.
30. Javed S, Panwar A. Effect of biofertilizer, vermicompost and chemical fertilizer on different biochemical parameters of Glycine max and *Vigna mungo*. Recent Res. Sci. Tech. 2013;5(1):40-44.
31. Joseph PV. Efficacy of different substrates on vermicompost production. In: Organic Fertilizers-History, Production and Applications (Eds. Larramendy M and Soloneski S) Intech Open; c2019. DOI: 10.5772/intechopen.86187.
32. Kagne SV, Bavalgave VG, Waghmare MS, Bodake BL. Response of fertilizers and organic manure on growth, yield and quality of sweet sorghum. Asian J. Soil Sci. 2008;3(2):313-315.
33. Kansotia BC, Sharma Y, Meena RS. Effect of vermicompost and inorganic fertilizers on soil properties and yield of Indian mustard (*Brassica juncea* L.). J. Oilseed Brassica. 2015;6(1):198-201.
34. Kasuhik J, Singh R. Effect of levels of vermicompost and biofertilizers on growth and yield of organic lentil (*Lens culinaris* Medik). The Pharma Innov. J. 2022;11(2):1688-1691.
35. Khan VM, Ahamad A, Yadav BL, Mohammad I. Effect of vermicompost and biofertilizers on yield attributes and nutrient content and it's their uptake of cowpea [*Vigna unguiculata* (L.) Walp.]. Int. J. Cur. Microbiol. Appl. Sci. 2017;6(6):1045-1050.
36. Kumar S, Rawat CR, Shiva D, Rai SK. Dry matter accumulation, nutrient uptake and changes in soil fertility status as influenced by different organic and inorganic sources of nutrient to forage sorghum (*Sorghum bicolor* L.). Indian J. agric. Sci. 2005;75:340-342.
37. Lim SL, Wu TY, Lim PN, Shak KP. The use of vermicompost in organic farming: overview, effects on soil and economics. J Sci. Food Agri. 2015;95(6):1143-1156.
38. Mahmoud SO, Gad DAM. Effect of vermicompost as fertilizer on growth, yield and quality of bean plants (*Phaseolus vulgaris* L.). Middle East J Agri. Res. 2020;9(1):220-226.
39. Manivannan S, M Balamurugan, K Parthasarathi, G

Gunasekaran, LS Ranganathan. Effect of vermicompost on soil fertility and crop productivity-beans (*Phaseolus vulgaris*). J. Environ. Biol. 2009;30(2): 275-281.
40. Mathivanan, S, Kalaikandhan R, Chidambaram AL, Sundramoorthy P. Effect of vermicompost on the growth and nutrient status in groundnut (*Arachis hypogaea* L.). Asian J. Pl. Sci. Res. 2013;3(2):15-22.
41. Mycin TR, Lenin M, Selvakumar G, Thangadurai R. Growth and nutrient content variation of groundnut (*Arachis hypogaea* L.) under vermicompost application. J. exptl. Sci. 2010;1(8):12-16.
42. Nagavallemma KP, Wani SP, Stephane L, Padmaja VV, Vineela C, Baburao M, Sahrawat KL. Vermicomposting: Recycling wastes into valuable organic fertilizer. In: Global Theme on Agrecosystems Report No. 8. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, India; c2004. p. 20.
43. Paliwal DK, Kushwaha HS, Thakur HK. Performance of soybean [*Glycine max* (L.) Merrill]-wheat (*Triticum aestivum*) cropping system under land configuration, mulching and nutrient management. Indian J. Agron. 2011;56(4):334-339.
44. Parthasarathi K, Balamurugan M, Prashija KV, Jayanthi L, Basha SA. Potential of *Perionyx excavatus* (Perrier) in lignocellulosic solid waste management and quality vermifertilizer production for soil health. Int. J Recycl. Org. Waste Agri. 2016;5(1):65-86.
45. Pathma J, Sakthivel N. Microbial diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential. Springer Plus. 2012;1:26.
46. Pathma J, Sakthivel N. Molecular and functional characterization of bacteria isolated from straw and goat manure based vermicompost. Appl. Soil Ecol. 2013;70:33-47.
47. Patil TD. Effect of rates of castor cake and banana pseudostem sap on yield and quality of organically grown garlic. Ph.D. (Thesis), Navsari Agricultural University, Navsari, Gujarat; c2013.
48. Patra PS, Sinha AC, Mahesh SS. Yield and yield attributes nutrient uptake and quality of groundnut (*Arachis hypogaea*) kernals as affected by organic sources of nutrient. Indian J. Agron. 2011;56(3):237-241.
49. Perner H, Schwarz D, George E. Effect of mycorrhizal inoculation and compost supply on growth and nutrient uptake of young leek plants growth on peat-based substrates. Hort Sci. 2006;41:628-632.
50. Postma J, Montanari M, Van den Boogert PHJF. Microbial enrichment to enhance disease suppressive activity of compost. Eur. J Soil Biol. 2003;39:157-163.
51. Rana R, Badaliya D. Effect of integrated nutrient management on seed, quality and nutrient uptake of soybean (*Glycine max* L.) under mid hill condition of Himachal Pradesh. Indian J Agron. 2014;59(4):641-645.
52. Randhe MV, Jadho SD, Mane SS. Effect of organic and inorganic fertilization on yield and quality of wheat. Green Fmg. 2009;2(1):924-927.
53. Reddy R, Reddy M, Reddy YTN, Reddy NS, Anjanappa N, Reddy R. Effect of organic and inorganic sources of NPK on growth and yield of pea (*Pisum sativum* L.). Legume Res. 1998;21(1):57-60.
54. Sahin Ö, Taşkın MB, Kaya EC. Effect of phosphorus application on element concentrations of lettuce and onion plants. Nevşehir Bilim ve Teknoloji Dergisi, TAGRID; c2016. Special Issue: 150-160.
55. Sharma KC, Agrawal RK. Effect of chemical fertilizers and vermicompost on the productivity and economics of forage sorghum and their residual effects on oat. Range Mgt. Agroforest. 2003;24:127-131.
56. Sharma RC, Banik P. Vermicompost and fertilizer application: effect on productivity and profitability of baby corn (*Zea mays* L.) and soil health. Compost Sci. Util. 2003;22:83-92.
57. Singh A, Singh GS. Vermicomposting: A sustainable tool for environmental. Environmental Quality Management. 2017;27(1):23-40.
58. Singh R, Prasad K. Effect of vermicompost, Rhizobium and DAP on growth, yield and nutrient uptake of chickpea. J Food Legumes. 2007;21(2):112-114.
59. Singh R, Sharma RR, Kumar S, Gupta RK, Patil RT. Vermicompost substitution influences growth, physiological disorders, fruit yield and quality of strawberry (*Fragaria* x *ananassa* Duch.). Bioresour. Technol. 2008;99:8507-8511.
60. Singh S, Mehta AK, Thakral SK. Nutrient content and their uptake in wheat as affected by vermicompost and inorganic fertilizers. Haryana J. Agron. 2007;23:106-108.
61. Sinha RK, Heart S, Valani D, Chauhan K. Vermiculture and sustainable agriculture. Am.-Eurasian. J agric. environ. Sci. 2009;5(S):1-55.
62. Sreenivas C, Muralidhar S, Rao MS. Vermicompost: a viable component of IPNSS in nitrogen nutrition of ridge gourd. Ann. Agric. Res. 2000;21(1):108-113.
63. Shrimal P, Khan TI. Effects of vermicompost on biochemical parameters of Bengal gram (*Cicer arietinum* L.) var. RSG-896 under field conditions. Inter. J. Adv. Res 2017;5(5):661-666.
64. Suhane RK. Vermicompost (In Hindi). Publication of Rajendra Agriculture University, Pusa, Bihar; c2007. p.88.
65. Tharmaraj K, Ganesh P, Kolanjinathan K, SureshKumar R, Anandan A. Influence of vermicompost and vermiwash on physico-chemical properties of rice cultivated soil. Cur. Bot. 2011;2(3): 18-21.
66. Tomati U, Grapelli A, Galli E, Rossi W. Fertilizers from vermiculture as an option for organic waste recovery. Agrochimiya. 1983;27:244-251.
67. Tomati U, Grappelli A, Galli E. The presence of growth regulators in earthworm-worked wastes. In: Proceedings of International Symposium on Earthworms (Eds. Bonvicini Paglioi, A.M. and Omodeo, P.). Selected Symposia and Monographs, Unione Zoologica Italiana, 2, Mucchi, Modena; c1987. p. 423-435.
68. Vasanthi D, Subramanian S. Effect of vermicompost on nutrient uptake and protein content in black gram (*Cicer arientinum*). Legume Res. 2004;27(4):293-295.
69. Vasoya UJ. Effect of organic manure and biofertilizer on growth and yield of direct seeded rabi fennel (*Foeniculum vulgare* Mill.). M.Sc. (Agri.) Thesis, Junagadh Agricultural University, Junagadh, Gujarat; c2014.
70. Werner M, Cuevas R. Vermiculture in Cuba. JG Press Inc, 63 S 7th St Ste 5 Emmaus, PA 18049; c1996.
71. Zhao H, Li T, Zhang Y, Hu J, Bai Y, Shan Y, Feng K. Effects of vermicompost amendment as a basal fertilizer on soil properties and cucumber yield and quality under continuous cropping conditions in a greenhouse. J Soils Sediment. 2017;17:2718-2730.