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REVIEW ARTICLE

PROSPECTS OF VERMICOMPOSTING IN ABIOTIC STRESS MANAGEMENT

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ABSTRACT

Climate change due to global warming and changing agricultural practices such as overuse of inorganic fertilizers, pesticides, herbicides etc., deteriorates the environmental stability. It creates abiotic stresses in the agricultural sector, especially in arid and semi-arid regions. The different abiotic stresses such as soil salinity, acidity, deficient or excess moisture, drought, metal toxicity, reduced soil health, land degradation etc., severely affect agricultural productivity and farmers' income. Hence, there is a need to find an environment-friendly and economically viable farming method that can eliminate the negative impacts of abiotic stresses on plant yield. Using organic fertilizers like animal manure and composted materials enhances a healthy ecosystem. Vermicomposting is now widely recognized for converting organic materials into nutrient-rich fertilizer and soil conditioner. This review summarizes the Importance of vermicomposting in managing different abiotic stresses through its positive impact on soil and ecosystem. Vermicompost application improves soil structure and microbial activity to combat soil stress. It reduces water stress by managing soil-air-water relation and maintain long-term soil fertility by providing macro and micronutrients in optimum quantity. The different experimental investigations suggested using vermicompost and vermiwash to mitigate abiotic stresses and can be helpful for sustainable agriculture.

KEYWORDS: Earthworms, Vermicomposting, Vermiwash, Abiotic stress

INTRODUCTION

After the onset of the green revolution (1965-66), food production significantly increased due to intensive farming and imbalanced agrochemicals. This intensification of agriculture boosted food production but had a detrimental effect on the environment and society. Heavy use of agrochemicals destroyed soil's natural fertility, killed many beneficial soil organisms, and impaired the power of 'biological resistance' in crops, making them more susceptible to insect pests and diseases. In addition, several anthropogenic activities have released greenhouse gases, one of the major factors for climate change and, in turn, the frequent occurrence of abiotic stresses in agriculture.

Nowadays, abiotic stresses are major constraints in agricultural crop production across the globe. It includes physical and chemical stresses such as solar radiation, temperature (high and low), moisture (both excess and deficit), soil salinity, alkalinity, nutrient availability, agrochemical contaminations in soil and water resources etc., impacting the growth and productivity of the crop. Furthermore, abiotic stresses also interact with biotic stresses making the plant more susceptible to infestations (Mariani et al., 2017; Gull et al., 2019). Around 91% of the world's agricultural area is afflicted by abiotic stresses, leaving only 9% suitable for crop production (Minas et al., 2017). Thus, the scientific community worldwide is looking for viable options for managing agriculture in abiotic stressed regions for sustainable crop production.

The demand for 'natural and organic food' is increasing day by day. Therefore, organic farming is regaining momentum among the stakeholders as an alternate strategy for mitigating the effects of abiotic stresses for sustainable crop production. Vermicompost amendment is a well-known strategy to enhance the health of degraded soil, availability of mineral elements, increasing soil productivity, and reduce the effects of abiotic stresses via improving soil structure. In addition, vermicompost can reduce the harmful effects of various environmental stresses on plants due to its porous structure, high water storage, hormone-like substances and high levels of macro and micronutrients (Saeed and Raheleh, 2018).

WHAT IS VERMICOMPOSTING?

Vermicomposting produces compost by utilizing earthworms to turn the organic waste into high-quality compost consisting mainly of worm cast and decayed organic matter (Ismail, 2005; Devi and Prakash, 2015). Vermicompost is an organic fertilizer rich in NPK, micronutrients and beneficial soil microbes, a sustainable alternative to chemical fertilizers, an excellent growth promotor and protector to crop plants (Sinha et al., 2011; Chauhan and sing, 2015). Vermicompost is a finely divided peat-like material with excellent structure, porosity, aeration, Draining and moisture holding capacity (Ismail, 2005; Edwards et al., 2011). Vermicompost application is an effective way to maintain soil health and productivity.

PREPARATION OF VERMICOMPOST

Generally, the bed method is considered easy to prepare vermicompost in a pit or PVC sheet. The entire process of vermicomposting in PVC sheet of size 12×8×2 feet is mentioned below (Flow chart A and Fig 1-8).

Collect the biomass and dry it under the sun by keeping for about 8-12 days

⇓

Use this biomass for preparation as basal layer

⇓

Add (6-8) cm thick layer of soil or sand to ensure proper drainage

⇓

Prepare a layer of moistened loamy soil up to the height of 15 cm and inoculation of earthworms into it. For eg. *Eisenia foetida*

⇓

Scatter lumps of fresh or dry cattle dung over the moistened soil.

⇓

Cover the soil with dry grass clippings or farm waste up to 10 cm thickness

⇓

The unit should be covered properly to protect the earthworms from birds and sunlight

⇓

It should be kept moist by sprinkling water twice a week

⇓

Maintain proper moisture and temperature and avoid the compost from overheating

⇓

Turning should be done once a week to ensure proper decomposition

⇓

The compost would be ready within 60-90 days by decomposition.

Flow Chart A: Different steps to prepare the vermicompost

1. Basal layer preparation using crop biomass

2. A layer of moistened loamy soil

3. Scattering lumps of fresh or dry cattle dung

4. Covering with dry grass clippings or farm waste

5. Sprinkling of water to maintain moisture

6. Turning to ensure proper aeration

7. **Seiving of Prepared Vermicompost**

8. **Harvested Vermicompost**

Fig 1-8. Preparation of vermicompost

CHARACTERISTICS OF VERMICOMPOST

The nutrient content of vermicompost is generally higher than the compost prepared traditionally with the same raw material.

Table 1: Nutrient analysis of vermicompost

S. No.	Parameters	Content
1	Organic Carbon (%)	9.15 - 17.88
2	Total Nitrogen (%)	0.5 – 0.9
3	Total Phosphorus (%)	0.1 – 0.26
4	Total Potassium (%)	0.15 – 0.256
5	Total Sodium (%)	0.055 – 0.3
6	Calcium & Magnesium (Meq/100 g)	22.67 – 47.6
7	Copper (mg L^{-1})	2.0 – 9.5
8	Iron (mg L^{-1})	2.0 – 9.3
9	Zinc (mg L^{-1})	5.7 – 9.3
10	Sulphur (mg L^{-1})	128.0 – 548.0

(Source: Sreenivas et al., 2000)

ROLE OF WORMS IN VERMICOMPOSTING

Aristotle referred to earthworms as "the intestines of earth and the restoring agents of soil fertility" (Shipley, 1970). A good population of earthworms are an indicator of healthy soil containing a large population of bacteria, fungi, viruses and insects (Lachnicht and Hendricx, 2001); therefore, they are also called as "Ecosystem Engineers". A status report prepared by CAPART recommended that *Eisenia foetida* is best-suited species throughout India whereas, *Eisenia Eugenie*, *Perionyx excavates*, *Perionyx sansibaricus* are best suited for southern parts of country (Kumar C.A., 1994)

Earthworm gut is an effective tubular bioreactor consisting of 73% gram-negative, facultative anaerobic, Vibrio sp. which degrade the ingested food and produce wormcast. The glands are present in the earthworm gut's anterior region that produces mucus, thereby providing a favorable substrate for symbiotic microorganisms to decompose complex organic compounds (Rajendran et al., 2008). Wormcast also contains enzymes like amylase, lipase, protease, cellulase and chitinase, which, even after excretion, continue to disintegrate organic matter (S. A. Abbasi, 2001). Earthworms rapidly convert waste into humus substances having finer structure and more diverse microbial activity (Atiyeh et al., 2000). A schematic diagram showing the beneficial role of earthworms (Fig 2).

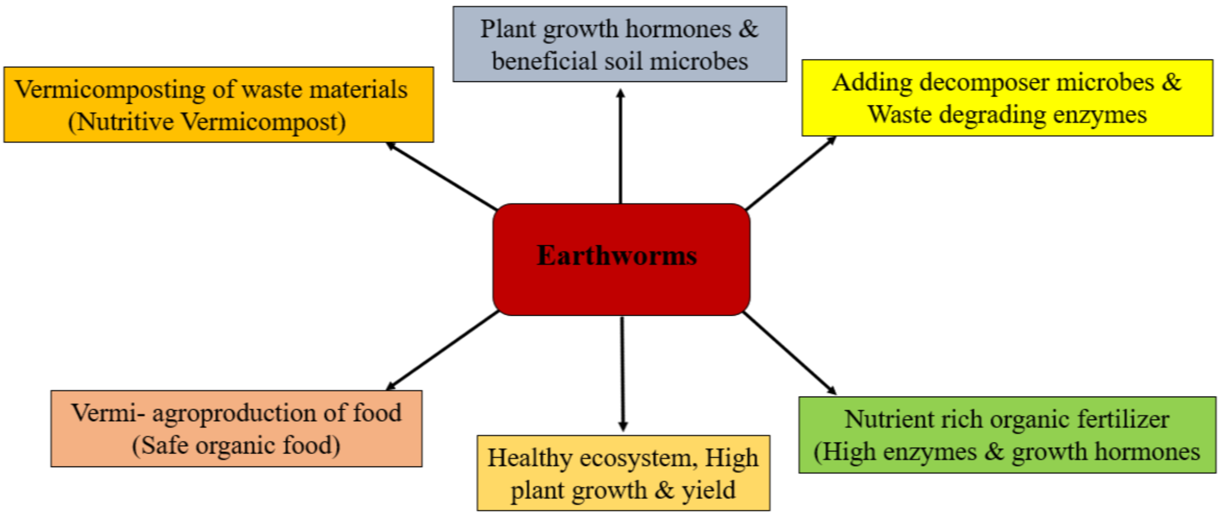

Fig 2. Role of Earthworm in vermicomposting

(Source, Adapted from Rajiv K. Sinha, 2009)

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VERMIWASH

Nowadays along with vermicompost, vermiwash is also gaining Importance in sustainable agriculture for its origin, cost-effectiveness, easy availability, reproducibility and eco-friendliness (Zambare et al., 2008). Vermiwash is a liquid collected after the passage of water through different layers of earthworm culture units. It contains not only the excretory products and mucus secreted by earthworms but also micronutrients associated with soil organic molecules. Vermiwash is a liquid fertilizer used as foliar spray to transport leaves, shoots and other plant parts. If collected properly, it appears like clear, transparent or pale yellow-coloured fluid (Ismail, 1997). Vermiwash possesses the inherent property of acting as a fertilizer and mild biocide (Pramoth, 1995). Vermiwash, the extracted body fluid of

Table 2: Nutrient analysis of vermiwash

S. No.	Parameters	Content
1	pH	7.39-7.5
2	EC	0.008±0.001
3	Organic Carbon	0.25 ± 0.03%
4	Nitrogen	0.01-0.001%
5	Phosphorus	1.70%
6	Potassium	26 ppm
7	Sodium	8 ppm
8	Calcium	3 ppm
9	Copper	0.01 ppm
10	Iron	0.06 ppm
11	Magnesium	160 ppm
12	Manganese	0.60 ppm
13	Zinc	0.02 ppm
14	Total heterotrophs (cfu/ml)	1.79 × 103
15	Nitrosomonas (cfu/ml)	1.01 × 103
16	Nitrobacter (cfu/ml)	1.12 × 103
17	Total Fungi (cfu/ml)	1.46 × 103

(Source: http//www.erfindia.org/vermiwash.asp)

earthworms, is nutrient-rich and possesses good plant growth-promoting components (Gorakh et al., 2009). Therefore, it can be effectively used for sustainable plant production at a low input basis green farming (Edwards et al., 2004). Weerasinghe et al. (2006) revealed that for tea, coconut and horticultural crops, vermiwash acts as a natural growth supplement.

IMPORTANCE OF VERMICOMPOSTING IN ABIOTIC STRESS MANAGEMENT

A) MANAGING SOIL STRESS

Soil stress includes several soil constraints such as soil salinity, alkalinity, structural deterioration, hard pans, shallow soils, surface sealing, metal contamination, low organic matter, etc. The use of vermicompost and vermiwash can mitigate these problems. Manivannan et al. (2009), through their experiment on beans, concluded that the treatments receiving vermicompost and vermi+NPK showed a significant decrease in particle density and bulk density than NPK alone. Vermicompost application enhances microbial population and activity, which form soil aggregates and thus increase soil porosity and thereby improving soil structure. Vermicompost had a considerable buffer capability as it increased soil pH in acidic soil and reduced it in alkaline soil (Fernandez-Bayo et al., 2009), thus found that its additions changed soil pH to neutral levels. Manivannan et al. (2009) experimented on clay loam soil and sandy loam soil and showed that application of vermicompost @ 5 tonnes ha^{-1} reduced pH (1 and 1.02 times) and EC (1.4 and 1.2 times), increased organic Carbon (37 and 47 times), in both soil types. Applications of osmoprotectants and antioxidants, i.e. vermicompost, glycine betaine and proline singly or in sequence, shows positive effect under irrigation with saline water stress condition. These also enhance ROS (Reactive oxygen species) scavenging and metal ion chelating, which forms a crucial part of abiotic stress responses in plant cells (Ezzat et al., 2019).

More than 800 million hectares of land throughout the world contain stressful salt ion concentrations for plant growth (FAO 2008). Soil salinity is one of the most severe environmental stresses which reduces productivity as well as the yield of agriculture. Excessive salt concentration leads to structural degradation, decreases soil microbial activity and alters soil osmotic and metric potential (Oo et al., 2015). It also affects plants' biochemical and physiological pathways. To overcome these problems, using vermicompost is one of the best solutions to present farming. Both vermicompost and vermiwash contain humic substances which act as activators of physiology as well as nutrient absorption and help to mitigate the stress of salinity (Reyes-Perez et al., 2014).

Table 3: Scientific evidence of vermicompost in managing soil salinity stress

Sr. No.	Findings	References
1.	Earthworms and Arbuscular mycorrhizal fungi cooperatively increased maize salt tolerance and growth under high salt stress by improving soil macroaggregates and decreasing salt concentration, followed by enhancing plant mineral assimilation (K, Ca, Mg), osmotic regulation and improving photosynthetic efficiency.	Zang et al. (2018)
2.	Earthworms reduced salt concentration in soil by increasing porosity, aeration, leaching of exchangeable Na^{+}, and adding organic matter. It also improves soil CEC and thereby increases Na^{+}- Ca^{2+} exchange.	Oo et al. (2015) and Wang et al. (2016)
3.	The survival of tamarind (*Tamarindus indica*) was only 20% after 80mM NaCl addition, but it was increased up to 85% with vermicompost. Without vermicompost, plant growth and photosynthesis were reduced by two-fold at 20mM NaCl, but with vermicompost, there was no inhibitory effect. Vermicompost limits salinity's negative effect on the tamarind plant's growth.	Maria et al. (2008)
4.	It was found that vermicompost is an appropriate growing media for vegetable seedling propagation during the nursery period even under salinity stress conditions due to enhanced plant physiological efficiency. In addition, a higher growth rate was provided during the stand establishment time.	Sallaku et al. (2009)
5.	The addition of Vermicompost and vermiwash in saline soil minimized the influence of salinity stress on growth parameters, viz. plant height, stem diameter, fresh and dry weight, and tuber characteristics such as pH and EC and total soluble sugars in potato plants. Furthermore, when NaCl concentration in soil increased, the total sugar concentration in potatoes also increased due to adaptive mechanisms in potato plants after the application of vermicompost.	Jose de Jesus Perez-Gomez et al. (2017)

6.	Commercial tomato seedlings showed improved root growth, higher no. of leaves, increased leaf area, increased total sugars and chlorophyll content and greater stem thickness after vermicompost leachate (VCL) treatment, even at high NaCl- tested concentration (100 mM). VCL- treated seedlings showed more tolerance to osmotic and oxidative stress due to the accumulation of compactible solutes such as proline.	Mayashree Chinsamy et al. (2013)

B) MANAGING WATER STRESS

Water stress is one of the plants' most frequent and damaging abiotic stressors, which highly reduces yield. The production of ROS (reactive oxygen species) might increase in plants under water-stress conditions. This ROS production may promote damaging processes and provide signals for adaptation to environmental changes (Jubany-Mari et al., 2012). Humic acid in vermicompost affects plant hormonal regulation and root growth pathways (Mora et al., 2010).

Table 4: Scientific evidence of vermicompost in managing water stress:

Properties	Findings	References
Grain Yield	At 50% field capacity, the control plot gives a 3.06 ton/ha grain yield. Application of Vermicompost increases yield up to 3.76 ton/ha and vermi.+ Biochar gives the highest yield of 4.38 ton/ha under water stress in saline-sodic soil due to its positive effect on soil physicochemical properties.	Emad M.H. et al. (2020)
Water retention	Application of Vermicompost increases macropore space in soil ranging from 50-500 µm, which improves air-water relation in soil and thereby favourably affect plant growth.	Marinari et al., (2000)
	Vermicompost contain absorbent organic matter which holds water according to plant roots requirement and thus increases water retention capacity of soil	Kumar A., (2005).

Plant traits	Addition of 30% vermicompost under moderate and severe water stress conditions increases plant height, no. of pods, leaf area, dry weight, carotenoids in chickpea and its water use efficiency over control.	Hamzeh Amiri et al. (2017).
	The application of humic acid protected cell membrane permeability in rice crop under water loss condition	Gracia et al. (2012).
WHC	WHC, Porosity and moisture content recorded initially were 41%, 34% and 36% respectively and the increased respective values were 49%, 44% and 46% after application of vermicompost and vermiwash.	Tharmaraj et al. (2011)
ABA Content	In water stress condition, the ABA content was increased in roots and leaves of rice plant. However, when water stress was associated with treatment humic acid from vermicompost, the ABA level was similar to those plants without water stress.	Gracia et al. (2014)
Growth and Yield	Vermicompost improved maize growth and yield but its effect was only significant when water availability was limited. This suggested vermicompost's promising role in improving agrosystem resistance to water stress.	Doan et al. (2015)

C) MANAGING NUTRIENT STRESS

Vermicompost has higher nutritional values than traditional compost because of increased rates of mineralization and degree of humification by the action of earthworms (Azarmi et al., 2009). It is ideal organic manure for the growth and yield of plants as it is a nutrient-rich organic fertilizer. It is rich in NPK, Micronutrients, plant growth hormones and enzymes. Therefore it acts as a ‘growth promoter' and 'plant protector'. It is highly porous and has a large surface area, retaining nutrients for longer than conventional compost. Also, it acts as a 'slow-release fertilizer', lowering the soil's nutrient depletion. The nutrients present in vermicompost in such a form that can be readily absorbable by plants, such as nitrates, exchangeable Phosphorus, soluble Potassium, calcium and magnesium (Manivannan et al., 2009, Prabha ML, 2009). Nitrogen in vermicompost is mostly present in Nitrates form rather than ammonical form (Atiyeh et al., 2001).

Singh M. and Kundan Wasnik (2013) concluded that the available NPK in the soil after harvesting of the crop was found to be highest in treatments receiving vermicompost (12 t ha^{-1}) + Fertilizer NPK (100:25:25 kg ha^{-1}) than NPK alone. This was due to the slow mineralization of nutrients from vermicompost than chemical fertilizers. Humic acids in vermicompost enhance nutrient uptake by the plants as it increases the permeability of root cell membrane, stimulating root growth and increasing the proliferation of root hairs (Pramanik et al., 2007). Vermicompost is a soil conditioner, and its continuous application improves soil quality and fertility, even in degraded and sodic soils. Application of Vermicompost @ 6 tons/ha increased available Nitrogen by 829.33 kg/ha and reduced sodicity (ESP) by 73.68 (Sinha et al., 2008).

D) IMPROVEMENT IN SOIL BIOLOGICAL PROPERTIES

Several authors have noted that the soil microbial community can be changed and improved by earthworms. Vermicompost not only adds useful microorganisms to the soil but also provides food for the existing microbes, increasing soil's biological properties and capacity for self-renewal soil fertility (Shiralipour et al., 1992; Ouedraogo et al., 2001). It consists of beneficial soil microbes like 'nitrogen-fixing bacteria' and 'mycorrhizal fungi, which acts as growth promotor and protectors (Sinha et al., 2009). The respiratory activity of the microbial community can be measured by dehydrogenase enzyme activity and was found to be greater in vermicompost than in commercial medium (Atiyeh et al., 2001).

Manivannan et al. (2009) reported that total microbial activity and population had been significantly enhanced in treatments where vermicompost and vermicompost +NPK were applied. Pramanik et al. (2007) demonstrated that vermicompost obtained from cow dung showed the highest abundance of the microbial population, i.e. total bacterial count was 73×10^{8}, cellulolytic fungi was $59\times10^{6,}$ and nitrogen-fixing bacteria was 18×10^{3}. This vermicompost shows the highest urease activity (15.84 µg NH_4-N/g/h) and acid phosphatase activity (200.45 µg *p*-nitrophenol/g/h). Greater phosphatase activity indicates greater nitrogen content of the substrate, which in turn results in higher microbial activity. Organic treatments can stimulate soil biological activity due to the synergism of soil and microorganisms present in organic material or stimulation of microbial growth by organic compounds added with vermicompost and manure (Marinari et al., 2000). An introduction of vermicompost is more meaningful than the direct introduction of earthworms into filed. If vermicompost is applied in the field for longer, it shows the sustenance of the microbial population. There is an increase in the density of microbes except for actinomycetes, even after two months of crop harvesting (Kale et al., 1992).

Many diseases and growth of parasitic fungi such as Pythium, Rhizoctonia and Verticillium are suppressed after applying an ample quantity of Vermicompost (Sing et al., 2008). It also inhibits the incidence and abundance of plant parasitic nematodes in the soil, such as Meloidogyne incognita in tobacco plants (Swathi et al., 1998), egg mass of Meloidogyne javanica (Ribeiro et al., 1998) and also a significant reduction in the populations of spider mites (*Tetranychus urticae*), mealy bugs (*Pseudococcus* sp.) and aphids (*Myzus persicae*) (Arancon et al., 2007)

E) CROP QUALITY AND YIELD

Vermicompost is nutrient-rich, microbiologically active, porous material which acts as a gradual and constant source of nutrients (Chaoui et al., 2003); hence when added to soil influences plant growth and yield. Therefore, it improves the quality of agricultural produce by supplying sufficient nutrients in the available form to crops. Crop growth, yield and quality of different field crops, vegetables, flower and fruit crops were effectively enhanced after the application of vermicompost as it improves various physical, chemical and biological soil properties (Alemu Degwale, 2016).

Table 5: Effect of Vermicompost in improving quality parameters and yield

Sr. No.	**Quality Parameters**	**Reference**
1.	Sugar, protein and chlorophyll contents of the root, shoot and leaf of beans, as well as pod length, number of seeds per pod, number of pods per plant and pod weight were higher.	Manivannan et al. (2009)

2.	Vermicompost+ Vermiwash (100g + 100ml) application on okra showed maximum plant height, fat content, protein content and higher nutrient quality of fruits.	Ansari A. and K. Sukhraj (2010)
3.	Vermicompost @7.5 t ha^{-1} supplemented with inorganic fertilizers on strawberry increased plant spread (10.7%), leaf area (23.1%), dry matter (20.7%) and total fruit yield (32.7%). In addition, fruits harvested from this treatment were firmer and had higher TSS, ascorbic acid content and lower acidity.	Singh et al. (2008)
4.	Vermicompost @6 t ha^{-1} showed the highest fruit yield, no. of fruits per plant, fruit length and eggplant height.	Maral Moraditochaee et al. (2011),
5.	The grain yield of wheat and soybean increased by 47% and 51%, respectively.	Baker et al. (2006)
6.	Vermicompost @6 t ha^{-1} gives more potato yield (21.41 t ha^{-1}) over control (4.36 t ha^{-1}) even in soil sodicity stress.	Ansari A.A. (2008)
7.	Vermicompost @8 t ha^{-1} +NPK (150:25:25 kg ha^{-1}) produced optimum herbage and oil yield of rosemary under semi-arid tropical conditions in Bangalore.	M. Singh and Kundan Wasnik (2013)

Vermicompost not only has a positive impact on plant growth and productivity but also increases the nutritional quality of some vegetable crops such as spinach (Peyvast et al., 2008), strawberries (Singh et al., 2008), lettuce (Coria Cayupán et al., 2009), sweet corn (Lazcano et al., 2011) and Chinese cabbage (Wang et al., 2010).

CONCLUSION

Abiotic stress has already emerged as a new threat to agriculture, especially in arid and semi-arid regions. It includes soil stress, water stress, nutrient stress and deterioration in the quality of the produce. Moreover, climate change causes fluctuations in rainfall, high temperature, poor quality of irrigation water etc. This contributes to the formation of abiotic stresses, which largely influence the productivity and income of the agriculture sector. Therefore, there is a need to find a highly economical and ecofriendly way of crop production. Organic and vermicompost-derived products are gaining popularity among farmers because of their huge advantages over the soil and the environment. Vermicompost can replace costly inorganic fertilizers, and gives sustainable production without any harmful effects on soil, plants and the environment. The present issue of the world about the quality and nutritious food products can be solved with organic amendments. Furthermore, many global problems about soil, such as salinity, sodicity, improvement in soil fertility, physicochemical properties, soil health and reduction in pests and diseases, and stresses related to water availability, can be resolved with vermicompost. Nowadays, vermiculture technology is a big step towards sustainable development in agriculture.

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