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Review Article

VERMIHORTICULTURE: AN HORTICULTURALLY VIABLE AND ENVIRONMENTALLY SUSTAINABLE TECHNOLOGY TO CHEMICAL FARMING

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ABSTRACT
Vermihorticulture offers an active approach to produce quality food in considerable quantities. Many studies indicate that vermicompost ensures healthy vegetables and fruits in countable yield. It is an extremely effective source to produce vegetables and fruits gaining early flowering, fruiting and production. It is evident that vermicompost produce fruit of comparable quality in terms of weight and size. The growth promoting hormones like auxins, gibberellins and cytokinins make it different with others. The earthworms are such good digesters that these rejuvenate the agro ecosystem and replenish it with ample of beneficial nutrients. Vermihorticulture is a sustainable technology as it aims to enhance degraded environment as well as human and plant health and ensures to fulfill our needs. With the growing population it is necessary to produce food in quantities as well as qualities to feed everyone which is easily possible with vermiculture.

Keywords: *Vermicompost, Vermiculture, Plant Growth Regulator*

INTRODUCTION
Horticulture is the primary activity on the globe and in every society it has most crucial role to play in sustaining life for living beings. Horticulture as it is practiced at present has been observed to be one of the polluter of the environment. Nature has given us enough to fulfill our needs but not our greeds. In the present materialistic age our needs are increasing and thus the exploitive type of farming for producing more and more to meet our demands for food, fibers, fuel, fruits and industrial goods etc. Such agriculture/ horticulture practice made heavy demands on water, fertilizer and farm power. The effect of such intensive cropping has resulted in deteriorating soil tilth and decreased organic matter content along with this consistent use of high level of chemical inputs is increasing pollution hazards and may result in further degradation of soil health, polluting water and atmosphere which indirectly affect productivity of crops, animals and ultimately adversely to human health. Therefore it becomes necessary to generate some method for sustainable horticulture. Vermi horticulture is an innovative and economically viable technology which converts organic waste into valuable product. Vermiculture Biotechnology is gaining acceptance for management of organic solid waste of diverse categories including leaf litters mixed with cow dung, leaf litters, agro-wastes like straws, feed residues, green leaves, grasses, toppings from trees, cattle shed wastes, kitchen wastes, animal dung (with the exception of droppings of poultry), vegetables / fruits / flower wastes from markets etc. This technology denotes the use of earthworms as versatile natural bioreactors for efficient biodegradation of organic solid wastes.
The chapter aims at analyzing various studies related to the impact of chemical vs. organic fertilizers on growth and yield of horticulture plants, nutritional status of fruit, and impact on human health, soil and environment.

Vermicompost Vs. Chemical Compost
Vermicomposts are organic materials, broken down by interactions between earthworms and microorganisms, in a mesophilic process (up to 25°C); to produce fully stabilized organic soil

amendments with low C: N ratios. They also have a high and diverse microbial and enzymatic activity, fine particulate structure, good moisture holding capacity, and contain nutrients such as N, K, P, Ca and Mg in forms readily taken up by plants. They contain both plant growth hormones and humic acids which can act as plant growth regulators.

Organic fertilizers are beneficial to soil, water, plant growth and gives better yield. Chemical fertilizers are hot because they are loaded with energy and fire where as organic fertilizers from natural sources are cool and nutritive as mother's milk. Vermi-Compost has high growth promoting value because of humus content, its high porosity, water holding capacity and drainage than chemical fertilizers. The enzymes of vermicompost continuously break the organic matter of soil and make nutrients available to the plants.

In today's era, farmers are applying heavy doses of chemical fertilizers and pesticides to produce big yields. The consistent use of chemicals (fertilizers or pesticides etc.) has decreased soil fertility and caused health problems to consumers. Few effects were observed caused by use of fertilizers in higher quantity than recommended doses have resulted in to detrimental effects on sensory and chemical components of horticultural products i.e. fruit colour and nutrient content.

Organic fertilizer have been proven as effective means for improving soil aggregation structure and soil fertility, increasing microbial diversity and population, improving the moisture holding capacity of soils, improving soil cation exchange capacity and increasing crop yield. Vermicompost contains most of the nutrients in plant available forms as nitrates, phosphate and soluble potassium.

Urea is highly concentrated nitrogenous fertilizer, containing 46% of nitrogen. Super phosphate contains 16-20% of phosphorus. Murate of potash contains 60% of potassium (ICAR, 1980). Vermicompost is a nutritive 'organic fertilizer' rich in NKP (nitrogen 2-3%, potassium 1.85-2.25% and phosphorus 1.55-2.25%), micronutrients, beneficial soil microbes like 'nitrogen-fixing bacteria' and 'mycorrhizal fungi' & plant growth hormones. They are scientifically proving as 'miracle plant growth promoters' much superior to conventional composts and chemical fertilizers.

With continued application of vermicompost the organic nitrogen tends to be released at constant rate from the accumulated humus and the net overall efficiency of nitrogen over a period of years is considerably greater than 50% of that of chemical fertilizers. Availability of phosphorus is sometimes much greater than that from inorganic fertilizers.

Suhane (2007) studied the chemical and biological properties of soil under organic farming (using vermicompost) and chemical farming (using chemical fertilizers-urea (N), phosphates (P) and potash (K). The study was made in Bihar, India where the farm soil is partly sandy being located in the Indo-Gangetic Plain. Natural fertility of the soil is eroded due to heavy use of agrochemicals over the last 50 years.

Table 1: Farm soil properties under organic farming and chemical farming

Chemical and biological properties of soil	Organic farming (Use of vermicompost)	Chemical farming (Use of chemical fertilizers)
Availability of nitrogen(kg/ha)	256	185
Availability of phosphorus(kg/ha)	50.5	28.5
Availability of potash(kg/ha)	489.5	426.5
Azatobacter(1000/gm of soil)	11.7	0.8
Phosphobacteria(100000/kg of soil)	8.8	3.2
Carbonic biomass(mg/kg of soil)	273	217

Source: Vermicompost; Suhane (2007)

Organic farming is not about only farming without chemicals but also about the environment, agricultural traditions, traditional seeds, animal welfare, farming communities' sensible energy use, soil and water

conversion. There is an urgent need of merging traditional method of horticulture practices with organic farming for sustained horticulture production. Organic farming is all about maintaining soil health and it entails producing the highest yield possible, in a sustainable, ecofriendly manner using a number of techniques.

Fliebach *et al.,* (2007) studied the changes in soil organic carbon and pH over 21 years of organic and conventional farming at reduced and normal fertilization intensity. The study also aimed at investigating soil quality in farming systems of the DOK-trial (D: bio-dynamic, O: bio-organic, K: german ‘‘konventionell’’ integrated) comparing two organic (bio-Dynamic and bio-Organic) and two conventional farming systems (‘‘Konventionell’’ with and without manure). They concluded that soil organic matter in farming systems of the DOK trial was positively affected by manure amendment after 21 years of plot management. Farming systems without manure showed the severest loss in soil organic matter over time. Manure amendment to soils, as an attribute of mixed farming systems, is proven again to exert positive effects. Soil is one of the most valuable resources so it is necessary to maintain health of soil to get return. Excessive mineral fertilization and irrational cultural practices contribute to reduce fertility and the organic matter contents. The vermicompost is an “organic fertilizer” produced by interactions between earthworms and soil microorganisms and it contains material with a high degree of maturity, high porosity, aeration, drainage, water storage capacity and microbial activity. There are several studies proving that consistent application of organic fertilizers has improved soil structure positively.

Nutritional Quality of Horticulture Products

Nutrients in food come from many sources. The majority of these sources are natural. Vegetables and fruits are major sources of vitamins and minerals along with other beneficial nutrients in human diet. Despite nutritional importance for human well being, the progress of organic farming has not increased in required amount because of ambiguity of quality and quantity of production by organic system. Present evidences clearly envisage that organic foods are significantly different in terms of their safety and nutritional content to those produced by chemical fertilizers. It has been demonstrated that organically produced foods have lower pesticides and nitrate content.

Nutrient Availability in Organic vs Inorganic Food

Organic plant products have more dry matter and minerals Fe and Mg and far less nitrates similarly more poly unsaturated fatty acids were found in organic animal products organic vegetables (Lairon, 2009).

Table 2: Differences in Nutritional Content between Organic and Conventional Vegetables: Mean Percent Difference for Four Nutrients in Five Frequently Studied Vegetables

Vegetable	Nutrient			
	Vitamin C	**Iron**	**Magnesium**	**Phosphorus**
Lettuce	+17	+17	+29	+14
Spinach	+52	+25	-13	+14
Carrot	-6	+12	+69	+13
Potato	+22	+21	+5	0
Cabbage	+43	+41	+40	+22

*(Source: Worthington, 2001)*Plus and minus signs refer to conventional crops as the baseline for comparison. For example, vitamin C is 17.0% more abundant in organic lettuce (conventional 100%, organic 117%).*

Lester (2007) cultivated whole grapefruits from each production system for three consecutive years. Within each harvest season, conventional and organic whole fruits were compared for marketable

qualities (fruit weight, specific gravity, peel thickness, and peel color), and juices were compared for marketable qualities (specific gravity, % juice, and color), human health-bioactive compounds (minerals, ascorbic acid, lycopene, sugars, pectin, phenols, and nitrates), and consumer taste intensity and overall acceptance. Organic fruit had a commercially preferred thinner peel, and the juice was higher in ascorbic acid and sugars and lower in nitrate. Worthington (2001) surveyed the existing literature comparing nutrient content of organic and conventional crops using statistical methods to identify significant differences and trends in the data. For each organic-to-conventional comparison, a percent difference was calculated. In the study mean percent difference values were calculated for each significant nutrient for the most frequently studied vegetables. On the basis of mean percent difference in nutrient content of five frequently studied vegetables, it can be concluded that organically grown vegetable had higher nutrient content i.e. Vitamin C, iron, magnesium and phosphorus as compared to conventionally grown vegetable (Table 2). The nutrient content of the daily vegetable intake was calculated for both an organic and conventional diet. Higher nutrient content was reported 27% more vitamin C, 21.1% more iron, 29.3% more magnesium, and 13.6% more phosphorus in organic crops. In addition, organic products had 15.1% less nitrates than their conventional counterparts. Nitrates can easily transform into nitrites. Nitrites are highly reactive molecules capable of contending with oxygen in blood circulation for binding hemoglobin, thus leading to methanoglobenemia and possible anoxia and binding secondary amines to generate nitrosamines which are among the most powerful natural cancer-promoting moieties.

Theunissen *et al.,* (2010) reported that vermicompost application should be manipulated to increase the metabolism of phenolic compounds sufficiently enough to improve the color and nutritional quality of the plants and the antioxidant activity of their edible or medicinal products for the benefits of the food industry.

Ismail *et al.,* (2003) investigated commercially available vegetables grown organically and conventionally, to analyze β-carotene and vitamin C contents. The ascorbic acid in Chinese mustard grown organically had recorded 124.8 mg /100 g of fresh weight and in conventionally grown Chinese mustard it was 114.7 mg/100 g of fresh weight. The organic swamp cabbage had the highest content of ß-carotene of 3503 µg/100 g fresh weight. Chinese mustard (1994 µg/100 g fresh weight) and lettuce (2006 µg/100 g fresh weight) grown conventionally had the lowest ß-carotene content among the vegetables. Glycoalkaloid levels tended to be higher in organic potatoes. In tuber skin and flesh, potassium, magnesium, phosphorus, sulphur and copper concentrations were also significantly higher in the organic treatments, while iron and manganese concentrations were higher in the skin of conventionally grown potatoes (Wszelaki *et al*., 2005; Bordeleau *et al.*, 2002).

Shankar and Sumathi (2008) observed vermicompost application to tomato crop cultivated in kharif registered significantly higher lycopene content compared to other organically grown tomato. Lycopene content of conventionally cultivated tomato was found to be significantly lower compared to all other treatments in both the seasons. Caris-Veyrat *et al.,* (2004) found fresh matter; organic tomatoes had higher vitamin C, carotenoids, and polyphenol contents (except for chlorogenic acid) than conventional tomatoes. Ansari and Sukhraj (2010) conducted an investigation focusing on recycling organic waste using vermitechnology and use of vermicompost and vermiwash obtained from the vermitech in varied combinations for exploring the effect on soil and productivity of okra (*Abelmoschus esculentus*). The study revealed that combination organic fertilizers vermicompost and vermiwash combination compared with control and chemical fertilizers had great influence on plant growth parameters. The average yield of okra (*A. esculentus*) during trial showed a significantly greater response in comparison with the control by 64.27%. The fruits were found to have a greater percentage of fats and protein content when compared with those grown with chemical fertilizers by 23.86 and 19.86% respectively.

A study was done to compare the sensory quality of apples *(Malus domestica Borkh*.) from the organic and conventional production. Organically grown apples showed higher content of soluble solids, total sugars and reduced sugars in comparison to the apples from the conventional orchards (Adamczyk *et al.,*

2005). The effect of excess nitrogen on the nutritional quality of crops has received considerable study. Excess N can diminish taste and flavor, lower resistance to diseases (rust and downy mildew), lower resistance to insect damage (mites and aphids), and reduce the biological value of plant protein (Schuphan, 1972). Excess N also can reduce carbohydrate synthesis; the resulting lower content of glucose can affect taste and flavor. Moreover, glucose is required for ascorbic acid synthesis, and the ascorbic acid content decreases in crops as available fertilizer nitrogen increases which is seen with chemical fertilizers (Hornick, 1992). Hoefkens *et al.,* (2009) studied on comparison of nutrient and contaminant contents between organic and conventional vegetables and potatoes, the increasing demand for organic foods is explained mainly by consumers concerns about the quality and safety of foods and their perception that organically produced foods are healthier and safer than conventional foods. They found that for nutrients and contaminants organic vegetables and potatoes score significantly better than conventional vegetable.

Theuer (2006) concluded that organic apples especially are usually preferred over conventional because of better taste than conventional apples. Barrett *et al.,* (2003) conducted the study of qualitative and nutritional differences in processing tomatoes grown under commercial organic and conventional production systems. They recorded higher levels of soluble solids, titratable acidity. Rossetto *et al.,* (2009) worked to observe the possible differences in the concentrations of free radical scavengers and substances functional, in different beet parts cultivated following organic and conventional procedures. Organic plants concentrated higher vitamin C content (6.7 - 16.6 mg/100 g) with respect to the conventional ones (4.1 - 9.1 mg/100 g); higher flavonoids content (0.5 - 5.2 mg rutin/g) and, when cooked, the pulp of organic beet maintained a higher polyamine content and higher amount of total carotenoids.

In a research conducted on comparing food quality of organic and conventional fruits and vegetables, a difference in food quality was found for nutritive value (vitamin C) and toxicity (nitrates and pesticides). This experiment shows significant differences between organic and conventional apples for the parameters volume, colour and the sugar-acid ratio. The volume and colour are external parameters that effect appearance. The sugar-acid ratio is the internal parameter with the greatest impact on taste (Bordeleau *et al.,* 2002).

Dangour (2009) reported that vitamin C, calcium, phosphorus, potassium, total soluble solids, titratable acidity, copper, iron, nitrates, manganese, ash, specific proteins, sodium, plant non-digestible carbohydrates, ß-carotene and sulphur were higher in organic foods. Significant differences in content between organically and conventionally produced crops were found in some minerals (nitrogen higher in conventional crops; magnesium and zinc higher in organic crops), phytochemicals (phenolic compounds and flavonoids higher in organic crops) and sugars (higher in organic crops). In analysis restricted to satisfactory quality studies, significant differences in content between organically and conventionally produced crops were found only in nitrogen content (higher in conventional crops), phosphorus (higher in organic crops) and titratable acidity (higher in organic crops).

Antioxidants in Organic vs Chemically Grown Food

Antioxidants are vital constituents in foods, promoting both plant and human well-being. They promote human health by neutralizing cell damage caused by free radicals and dioxygen or peroxide molecules, also called reactive oxygen or reactive nitrogen species. Plant antioxidants should be consumed daily. The level of antioxidants within an individual's bodies on a specific day reflects that person's diet in the previous few days. Levels in the body tend to spike within a few hours of consuming a meal high in total antioxidants, returning to baseline levels after a few more hours. 58.5 percent higher antioxidant levels were observed in sustainably grown corn than conventionally grown corn, while organically and sustainably grown marionberries had approximately 50 percent more antioxidants than conventionally grown berries (Lester *et al.,* 2007 and Reganold *et al.,* 2010). Organic plant products contain more anti-oxidant micronutrients such as phenols, salicylic acid. Albright (2014) quoted that organic fruits,

vegetables, and grains have several measureable nutritional benefits over conventional crops, according to a study published in the British Journal of Nutrition. Analyzing 343 peer-reviewed publications, researchers from the United Kingdom with the help of American Charles Benbrook of Washington State University found that organics contain 18 to 69 percent higher concentrations of antioxidants.

Sustainably and organically grown strawberries had about 19 percent more antioxidants than their conventional counterparts (Mitchell *et al.,* 2003). Peck *et al.,* (2004) reported that total antioxidant activity was 10-15% higher in organic apples than conventional apples and 5-12% higher than integrated apples.

Organic vegetable have more antioxidants than their conventionally grown counterparts. Organically grown foods are gaining popularity among consumers, health educators, farmers and food retailers. Many consumers believe that organically grown vegetables are of better quality, healthier and more nutritious than conventionally grown ones. Consumers consider organic foods to be more positive for the environment and human health and more flavorful than their conventionally grown counterparts.

Sensory Evaluation

Natural production system is beneficial to soil, water, plant growth and gives better yield. Fertilizers are hot because they are loaded with energy and fire where as organic fertilizers from natural sources are cool and nutritive as mother's milk. The organic production system uses the nature and thus produces healthy and tempting crops. A comparative study conducted by Unlu *et al.*, (2010) on quality properties of tomato cultivars grown using organic and conventional production systems studied the properties of tomatoes during storage at 13°C for 35 days. The results indicated that fruits grown using organic production system retained their firmness better during storage than their conventionally grown counterparts.

Bianchi *et al.,* (2010) studied the effects of organic and conventional production on the sensory characteristics of pac choi (cabbage) and tomato. ANOVA at a 95% confidence level was used to detect significant differences between treatments for individual attributes of flavour. Organic tomatoes grown in the field were generally juicier and less mealy compared to conventionally grown tomatoes and organic tomatoes were generally stronger in the characteristic tomato aroma.

Shankar and Sumathi (2008) conducted an experiment to evaluate effect of organic farming on nutritional profile of tomato crop. Tomato crop was grown using organic manures and chemical fertilizers. They found that the taste component of tomato puree prepared with vegetable grown with cow dung registered significantly higher scores compared to puree prepared with other crops. Aroma of tomato puree prepared with crops grown with organic manures (VC & FYM) resulted in significantly higher sensory scores compared to conventional crop. Overall acceptability of tomato puree prepared with crop grown with poultry manure, cow dung and farmyard manure was significantly different from control crop. Similarly mean sensory scores of tomato puree prepared with the crop cultivated using farm yard manure was also found to be significantly higher compared than other treatments.

Adamczyk *et al.,* (2005) conducted a study aiming to compare the sensory quality and selected physiochemical attributes of apples (*Malus domestica Borkh*.) from the organic and conventional production. Three-year studies were conducted on the following apple cultivars: Red Boskoop, Lobo and Janagold coming from three pairs of orchards. The sensory values of the organic apples were mostly similar and only in some cases higher compared to the conventional ones: juiciness in Lobo cultivar and hardness in Jonagold cultivar.

In the five yearlong investigation done by Velimirov (2003) on organic and conventional carrots (cultivar Tarvil) from 5 harvests (1998, 1999, 2001-2003) have been compared in relation to different quality aspects. They were grown in the same region assuring comparable sites and climatic conditions. Extended Triangle Test with the following procedures was applied for sensory evaluations. It could be demonstrated that carrots (var. Tarvil) grown in the Marchfeld (agricultural region near Vienna) revealed superior quality properties when grown on an organic farm as compared to conventional cultivation

methods. Organic carrots were significantly preferred for their carrot-typical taste and intense flavour as well as in juiciness and sweetness.

Taiwo *et al.,* (2002) cultivated okra (*Abelmoschus esculentus)* on, organic and chemical fertilizers. Okra soups produced from the okra fruits harvested from the various fertilizers treatments were subjected to sensory evaluation tests. In the sensory evaluation test of organically grown okra, panelists preferred organically grown okra soup to the chemically grown variant when they assessed the colour, taste, texture, flavour and drawness. Organically grown okra enjoyed more acceptability than the chemically grown. It was concluded that organically grown vegetables and fruits are preferred more because of their taste, colour, flavour and texture.

Gilsenan (2010) studied sensory qualities of organic and conventional tomato, potato and carrots. He stated in spite of so many advantages of organic farming if taste, colour, flavor are equal to the chemically fertilized products, it is much more beneficial than chemically fertilized vegetables. Excess N can diminish taste and flavor, lower resistance to diseases (rust and downy mildew), lower resistance to insect damage (mites and aphids).The effect of excess amount of chemical fertilizers on the nutritional quality of crops has received considerable study. Excess N reduces the biological value of plant protein and carbohydrate synthesis; the resulting lower content of glucose can affect taste and flavor. Moreover, glucose is required for ascorbic acid synthesis, and the ascorbic acid content decreases in crops as available fertilizer nitrogen increases. There are significant linkages between soil nutrient status, source of nutrient and the health status. Improving nutrient quality could enhance the nutritional quality, acceptability and bioavailability of foods.

The nutritional quality of fruits and vegetables is affected by many factors like soil factor, the variety of crop, climate, management practices and handling and storage. Soil differ in pH, porosity, cation exchange capacity, water holding capacity and mineral availability. These attributes vibrate the qualities of crop. Similarly, it is observed that vitamin C and thiamine content of vegetables are affected by light intensity. Most of the nutrients are affected by temperature, moisture, mycotoxins and aflatoxins etc. In the same way, extremes in temperature, water varied cultivars also affect noticeably. Higher chemical inputs in agro ecosystem cast doubt on food quality as well as safety.

Sustainability of Vermi Horticulture

It is not enough to produce sufficient food to feed the civilization. To beat the challenge of sufficient food supply to globe, green revolution techniques included developing high yielding varieties, mechanized tillage, artificially produced fertilizers and biocides and transgenic crops on the environmental cost, soil erosion, water (surface and ground) contamination, higher pest attacks due to increased resistance, more greenhouse gases and decreased biodiversity.

Vermihorticulture aims to produce a high quality nutritive food which should be safe (chemical free) and also protective to human health and to produce it in a sustainable manner to ensure food security for all, most importantly for the poor developing countries in the long term. It also offers the potential to reduce the need for these inputs in economically and environmentally sustainable way. It is a system of food production which avoids or largely excludes the use of systematically compounded chemical fertilizers and pesticides and use of environmentally friendly organic inputs. Sustainable agriculture satisfies increasing and changing human needs managing the resources for agriculture, together with preserving the quality of water, air and soil along with other natural resources,. Increasing organic wastes due to human activities in rural and urban areas and industries is globally a serious constraint in the maintenance of a clean and healthy environment. Earthworms are effective converters of these wastes (Munnoli, 2007; Suthar, 2008).

Vermiculture was practiced by traditional and ancient farmers with enormous benefits accruing for them and their farmlands. There is need to revive this ‘traditional concept’ through modern scientific knowledge and use of ‘Vermiculture Revolution’ Which uses earthworms. According to Sir Charles Darwin called the earthworms as ‘farmer’s friends’. There is great wisdom in this statement of the great

visionary scientist who advocated to use the earthworms, the 'nature's gift' in farm production (Sinha *et al.*, 2009). Lairon (2009) reported on the extensive review based on the AFSSA report issued and recently published studies that organic plant products contain more dry matter and minerals (Fe, Mg); and contain more anti-oxidant micronutrients such as phenols and salicylic acid, organic animal products contain more polyunsaturated fatty acids, 94–100% of organic food does not contain any pesticide residues, organic vegetables contain far less nitrates, about 50% less than conventional ones. Thus, organic agricultural systems have already proved their ability to produce food with high quality standards and proposed improvements of organic production to achieve sustainable food production for humans in the near future.

It was observed from the earlier studies that in the world of degraded environment and agriculturally hostile conditions earthworms and vermicompost are proving their tremendous growth promoting potentials and enhancing resistance to diseases in plants. The hormone like effect of earthworms, capacity to change soil structure and mineralization process results in higher availability of nutrients. Earthworms and their casts promote plant performance by reducing time of flowering and fruiting thus resulting in early maturity of fruit leads to early and higher yields without any need of chemical and protect plant from insects etc. Theunissen *et al.,* (2010) also suggested that with the global trend moving towards the production of organic food crops, organic waste material processed by the naturally occurring earthworm *Eisenia fetida* may be used to produce vermicompost which will supply nutrients and other soil stimulants for plant growth and improve soil quality which enhances plant growth and quality.

Thus vermihorticulture not only provides chemical free vegetables and food security but also enhances nutritive values and antioxidants availability in vegetables. Along with this it also provides disease resistance in plants and enhances soil quality leading to sustainability of vermihorticulture.

Plant Protection Qualities Leading to Sustainability of Vermi Horticulture

Earthworms along with its cast are excellent growth promoter as well as protector. Number of evidences has been found regarding ability of earthworms and vermicompost to protect plants against various pests and diseases either by creating resistance or by suppressing or by killing the pest and diseases through pesticidal action. The actinomycetes fungus excreted by the earthworms in their vermicast produce chemicals that kill parasitic fungi, such as Pythium and Fusarium (Edward and Arancon, 2004). Similar findings were given by Edwards *et al.,* (2007) that considerable suppression of root knot nematode (*Meloidogyne incognita*) and drastic suppression of spotted spider mites (*Tetranychus spp*.) and aphid (*M. persicae*) in tomato plants was seen after application of vermicompost teas (vermiwash liquid). They are serious pests of several crops. Treatments of growing media or soil with small amendments of different sources of vermicomposts can suppress plant pathogens and plant parasitic nematodes significantly, through microbial-based mechanisms. Hence, vermicomposts have considerable potential in integrated pest management programs, since one application can control the types of pest. Additionally, the microbial population present in vermicompost block the approach of plant pathogens to the plant roots and make them to starve which ultimately lead to decrease in spreading of pathogens. It is also evident that exoskeleton of some hard bodied insects is broken down by an enzyme "chitinase" secreted by earthworms.

It is generally agreed that the earthworms and its vermicompost and body liquid are scientifically proving as protector for crop plants because of the presence of some antibiotics and actinomycetes which improve biological resistance against pests and diseases.

Vermicompost: Promoting Plant Growth

Soil for horticulture should be conditioned to enhance seed nourishment and plant growth. Vermicompost has proven as miracle plant growth promoter. It contains a lot of traits which are highly beneficial for healthy growth of plant. Such traits are:

***High amount of luxuriant hormones*:** Either more or less nutrients exist in soil which helps in plant growth. Vermicompost stimulates and enhances seed germination, seedling growth and maturate, reduces

time of flowering, fruiting along with more productivity. It is all due to auxins, gibberellins and cytokinins exist in vermicompost. Pramanik (2007) reported that humic acids enhanced 'nutrient uptake' by the plants by increasing the permeability of root cell membrane, stimulating root growth and increasing proliferation of 'root hairs'.

***Slow steady release of safe nutrients*:** Nitrogen, phosphorus and potassium are more bio available for plants because of the action done by worms in their gut. Moreover these are released gradually and no aromatic hydrocarbon, pesticide/fungi/insecticide and heavy metal are present in vegetable and soil because of biodegrading action performed during vermicomposting by earthworms.

***Ample amount of humic acids*:** Out of many organic fertilizers, only vermicompost consist of humus (humic acid and fulvic acid). Humus makes the plant capable to utilize nutrients out of soil, stimulates root elongation and lateral root development and develops organic matter. It is secreted by earthworms in its excreta.

***Growth assisting beneficial micro organisms*:** Actinomycetes, Azotobacter, Rhizobium, Nitrobacteria and phosphate solublilizing bacteria exist in vermicompost in extraordinary amount. It is evident that microbes, including bacteria, fungi, actinomycetes, yeasts and algae, also produce plant growth regulators (PGRs) such as auxins, gibberellins, cytokinins, ethylene and ascorbic acids in appreciable quantities and as their population is significantly boosted by earthworms, large quantities of PGRs are available in vermicompost (Sinha *et al.*, 2009).

Some studies indicated that the growth responses of the plants from vermicompost appeared more like 'hormone- induced activity' associated with the high levels of nutrients, humic acids and humates in vermicompost (Atiyeh *et al.*, 2000).

Growth promoting hormones: Researches show that vermicompost use further stimulates plant growth even when plants are already receiving 'optimal nutrition'. It consistently improved seed germination, enhanced seedling growth and development, and increased plant productivity significantly much more than would be possible from the mere conversion of mineral nutrients into plant available forms (Sinha *et al.*, 2010). Some studies have also reported that vermicompost contained growth promoting hormone 'auxins', 'cytokinins' and flowering hormones 'gibberlins' secreted by Earthworms (Suhane, 2007).

The growth of plant is dependent on mineral element content of soil. Vermicompost is efficient nutritive fertilizer; it contains large concentrations of 2-3% nitrogen, 1.85-2.25% potassium and 1.55-2.25% phosphorus (Sinha *et al.*, 2011). Earthworms, vermicast and their body fluid release number of growth promoting soil enzymes like- urease, arylsulphatase promote germination, seedling growth and vegetative growth. Similarly higher numbers of fruit, early flowering and fruiting have resulted probably due to gibberellins, auxins and cytokinins. Beneficial soil microbes (nitrogen fixing and phosphate solublilizing bacteria), mycorrhizal fungi, and humus improve soil quality help to flourish the crop plants.

Beneficial Effects on Ecology, Human Health and Plant Health

It is a big responsibility to fulfill needs of the population through agricultural practices but in the present situation frequency of chemical application, in form of fertilizers and biocides, has increased. There are drastic impacts of such practices on plant and human health. It is evident that vermicompost and earthworms have capability to replenish, enhance and save the ecosystem.

Ecology

In recent years, the use of agrochemicals increased considerably. Air, ground water, rivers, lakes, rain water and fog water are contaminated by Chlorpyrifos. The contamination has been found up to 15 miles from the site of application. It is toxic to a wide variety of beneficial arthropods including bees, ladybird beetles and parasitic wasps. It kills fishes at concentrations as low as a few parts per trillion. Birds are also susceptible. Besides death, reduced weight and deformities in nestlings have resulted from chlorpyrifos exposure. Indiscriminate use of fertilizers, pesticides, insecticides and herbicides deteriorates the quality, texture and mineral content of the soil or which disturbs the biological balance of the organisms in the soil. Pollution in soil has adverse effect on plant growth.

Ground water gets contaminated by leaching of nitrate generated from fertilizers used in agricultural lands. Urea is an important fertilizer which gives nitrogen in the form of nitrates (NO3) to plants. When nitrogen fertilizers are used to enrich soils, nitrates may be carried by rain, irrigation and other surface waters through the soil into ground water if not utilized by the plants. Methemoglobinemia is caused by such contaminated water. Nitrates converted in to nitrite in human body, resulting in oxygen deficiency in body parts due to decreased ability of blood to carry oxygen causes this disease. Nitrate reacts with haemoglobin to form methemoglobin, a substance that does not bind and transport oxygen to tissues (Majumdar, 2003).

Vermicompost enhances soil microbes and essential nutrients because these release nutrient gradually whereas chemical fertilizers quickly relieve the nutrients in soil. The quickly relieved nutrients are not absorbed completely by the plants. The remaining nutrients seep down in the Earth and pollute water and soil. *E.fetida* and other earthworms can bio-accumulate chemicals in their tissues and either bio-degrade or bio-transform the chemicals into harmless products with the aid of enzymes. Sinha *et al.*, (2010) reported that *E . fetida* is most versatile bio-accumulator. It has been found to bio-accumulate heavy metals, pesticides and lipophilic organic micro pollutants, like the polycyclic aromatic hydrocarbon from the soil.

Human Health

Erratically used chemicals in chemical farming remain as residues and present risks like nervous breakdown, sterility, cancers, immunological disorders in adults and Blue baby syndrome, brain cancer, leukemia and birth defects in children. To safeguard health from all these diseases the miraculous farming alternative is Vermihorticulture. Vermi horticulture is free from synthetic chemicals so protect environment while chemicals used in conventional farming affect soil, water, human being and animal which collectively make life. Vermihorticulture is nature's way of farming.

It is concluded clearly by Theunissen *et al.*, (2010) that there is a huge potential in the use of vermicompost as it can play roles not only on the natural plant defence system, but also for human health benefits. Vermicompost tended to be higher in nitrates i.e. the more available form of nitrogen for plants (Atiyeh *et al.*, 2000).

Rusinek-Prystupa (2014) recommended that foods from organic farms have many health, nutritional and sensory benefits as compared with foods produced in the conventional systems. They contain fewer nitrate compounds, heavy metals and pesticide residues, while they have higher contents of certain vitamins, especially ascorbic acid and valuable proteins. The presence of flavonoids and anthocyanins compounds in many types of edible fruits and vegetables in modern diets provide natural pigmentation and possess a wide range of antioxidant protection and therapeutic benefits to human health, including potent cardio protective, neuroprotective, anti-inflammatory and anti-carcinogenic properties. There are strong experimental evidences indicating, organic plant products contain higher concentrations of health promoting secondary metabolites like flavonoids than chemical products. It might be due to lower input of fertilizer nitrogen.

Plant

The price of "safe vegetable" is still too high for the majority of people. High levels of agronomically beneficial microbial population in vermicompost protects plants by out-competing plant pathogens for available food resources that is, by starving them and also by blocking their excess to plant roots by occupying all the available sites. This concept is based on soil food-web studies (http://www.soilfoodweb.com).

Sinha *et al.*, (2009) reported that earthworms vermicompost is a nutritive 'organic fertilizer' rich in NKP, micronutrients, beneficial soil microbes- 'nitrogen fixing and phosphate solublizing bacteria' and 'actinomycets'. They are scientifically proving as excellent growth promoter and protector. Arancon *et al.*, (2002) reported that commercial vermicomposts, produced from cattle manure, food and recycled paper wastes, were applied at rates of 5 t/ha, 10 t/ha and 20 t/ha, to field plots planted with tomatoes

(*Lycopersicon esculentum*) bell peppers (*Capsicum anuum grossum*), strawberries (*Fragaria ananasa*) or grapes (*Vitis vinifera*).Control plots were treated with inorganic fertilizers only to evaluate nematodes populations. Populations of plant parasitic nematodes in all of the vermicompost treated soils were suppressed significantly for all crops ($P < 0.01$) compared to those in plots treated with inorganic fertilizers only. Populations of plant parasitic nematodes were larger in plots treated with inorganic fertilizer than in those to which no fertilizer was applied. Elmer (2009) reported that soil infested with soil borne pathogens and augmented with earthworm (*Lumbricus terrestris*) could reduce disease of susceptible cultivars of asparagus (*Asparagus officinalis*), eggplant (*Solanum melongena*), and tomato (*Solanum lycopersicum*). He found that earthworm activity was associated with an increase in plant growth similarly plant weights were increased 60 to 80%.

In long run agro ecosystem if food is produced through vermihorticulture it can contribute substantially to feeding the human population on current agricultural land, while maintaining soil fertility, ecosystem, human health and plant health. The practices and researches of vermihorticulture need to develop as a strong method for sustainable food production.

Conclusion

Vermi horticulture is more efficient, more productive and environment friendly in comparison to chemical horticulture. It is proving to be a reliable key to maintain soil, plant, environment and human health. Due to biological origin, vermicompost is blessing for ecosystem which includes human being, environment, plant and soil etc. They contain characteristics to replace chemical fertilizers with sustainable production conserving environment. It has been observed that earthworms and vermicompost enhances inner qualities of food, soil, plant which support human being in improving health status. The literature indicates that the use of earthworms and vermicompost can contribute to healthy ecosystem for future but it can also serve as a source of enrichment of soil, plant health, plant resistance along with nutritional value and sensory acceptability of horticultural products. It can be concluded by the comparisons that vermi horticulture is the sustainable method of agro production in respect to food security, and safety. Sinha *et al.,* (2010) extracted that vermicomposting and vermi-agro-production technologies if implied simultaneously, can maintain global human sustainability cycle using household as well as agricultural waste. The extensive data indicate that organic fertilizers are good for plant growth, yield, and soil health. With such qualities vermicompost and earthworms can be known as "gold input" for horticulture so there is strong need to switch over towards vermi horticulture and sustain health and ecosystem.

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