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MICROBIAL INNOVATIONS AND THEIR IMPACT ON FOOD SECURITY

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Introduction

Excessive use of chemical fertilizers and pesticides in agricultural lands over long period of time has resulted in poor soil health with combined effect on crop production and increase incidences of pests and diseases. These concerns have led to greater economic impact on farmers. Over the last few years the problems associated with food security has led to thinking in terms of organic agriculture by soil management techniques and microbial innovations. Soil microbiology influences above ground ecosystem by contributing to plant nutrition, health, soil structure and fertility. They also play a pivotal role in various biogeochemical cycles and cycling of organic compounds (Kirk *et al.,* 2004). Plant growth is improved when beneficial microbes increases nutrient availability and stimulates plant growth (Haynes and Krause, 2011). Biofertilizers, referred to the use of soil microorganisms to increase the availability and uptake of mineral nutrients for plant (Ansari, 2008), they are substance added to the soil to enhance the microorganisms, in order to increase the nutrient status. Vermicompost is one of the biofertilizers that helps to promote humification, increased microbial activity and enzyme production, which subsequently helps to increase the aggregate stability of soil particles resulting in better aeration when applied to the soil. The material has excellent structure, porosity, aeration drainage and moisture holding capacity, and helps to improve the physical, chemical and biological properties of the soil (Ansari, 2008).

The biocomposting method is made up of two phases (breakdown and buildup phase). In the breakdown phase biodegradable wastes are decomposed into smaller particles. Proteins are broken down into amino acids and finally to ammonia, nitrates and free nitrogen. Similarly, urea, uric acids and other non-protein nitrogen-containing compounds are reduced to form different plant nutrients. In the build-up phase, there is the re-synthesis of simple compounds into complex humic substances. The organisms responsible for transformation to humus are aerobic and facultative aerobic, sporing and non-sporing and nitrogen fixing bacteria of the *Azotobacter* and *Nitrosomonas* group. *Actinomycetes* also play an important role. There are two major reasons why vermicomposting is better. Waste is converted faster. Conventional composting takes weeks to months to convert organic matter to compost and are very labor intensive. By using earthworms, waste is rapidly turned into vermicompost. The vermicompost is far superior to conventional compost. The worm castings in the vermicompost have nutrients that are highly utilizable by plants and the castings have a mucous coating which allows the nutrients to "time release". Vermicompost forms fine stable granular organic matter that assist in the aeration, released mucus that are hygroscopic absorbs water and prevents water logging and improves water holding capacity. Vermicompost added to the soil releases nutrient slowly and consistently and enables the plant to absorb these nutrients more readily. Soils enriched with vermicompost provide additional substances that are not found in the chemicals (Ansari and Ismail, 2001; Kale, 1998). Biofertilizers contribute both macro and micro nutrients in amounts that are required by the plant and upon application have emphatic effect on plant growth parameters and production.

Organic waste possesses a serious environmental problem globally. This can be solved by Vermitechnology including Vermiwash and vermicompost, and also biodynamic preparation (500), which is essential component of biodynamic farming. Many researches over the years have been conducted, whereby solid waste were used and recycled to produce organic fertilizers using different technologies. In many developing countries there is a serious organic solid waste problem; preparing these organic fertilizers will be cost effective, and beneficial for farming (Ansari, 2009). The use of organic processes and materials in agriculture also helps to prevent environmental hazards, soil damage and nutrients loss due to the excess use of toxic chemical fertilizers and pesticides (Nath, *et al*., 2009).

Role of earthworm in soil fertility and microbial management

Earthworms are key to maintaining soil fertility and nutrient cycling. Earthworms process organic nutrients for the efficient growth of plants. Earthworms also contribute to the physical and chemical changes in the soil, transforming in terms of soil fertility and affect plant growth. Earthworms release casts into the soil which is enriched with beneficial microorganisms. Earthworms are classified into three ecological types. Epigeics (*Eisenia fetida, Eudrilus eugeniae*) are surface dwellers serving as efficient agents of comminuting and fragmentation of leaf litter. They are phytophagous and generally have no effect on the soil structure as they cannot dig into the soil. Anecics (*Lampito mauritii*) feed on the leaf litter mixed with the soil of the upper layers and are said to be geophytophagous. They may also produce surface casts generally depending on the bulk density of the soil. Endogeic earthworms (*Octochaetona thurstoni*) are geophagous and live within the soil deriving nutrition from the organically rich soil they ingest (Ismail, 2005).

Vermitechnology as Organic farming tool

Vermitechnology is a method of converting all the biodegradable wastes into useful product i.e. vermicompost, through the action of earthworms. Vermicompost is a sustainable bio-fertilizer regenerated from organic wastes using earthworm which contains 1.2 to 6.1% more nitrogen, 1.8 to 2.0% more phosphate and 0.5 to 0.75% more potassium compared to farm yard manure. It also contains hormones like auxins and cytokinins, enzymes, vitamins and useful microorganisms like bacteria, actinomycetes, protozoans, fungi etc (Ansari and Ismail, 2001). This process of decomposition results in the production of vermicompost. Vermicompost, or castings, is worm manure. It is considered by many in farming arena to be the very good soil improver. The nutrient content of castings is dependent on the material fed to the worms-and worms are commonly fed materials with high nutrient content (Ismail, 1997). It is the worm castings that provide these nutrients in a form that is readily available to plants. The biology of the worm's gut facilitates the growth of fungus and bacteria that are beneficial to plant growth.

Process of Vermicomposting

Vermicomposting is a simple biotechnological process of composting, in which epigeic species of earthworms are used to enhance the process of waste conversion and produce a better end product. Vermicompost is a nutrient rich organic soil conditioner which can be applied to improve soil conditions for a wide range of soil types. The use of earthworms is very essential in this process, as the worms act for the composing of organic matter into a stable nontoxic material with good structure, which has a potentially high economic value and also act as soil conditioner for plant growth. Vermicomposting has many environmental benefits is proven to be an easy way of getting rid of garbage waste. This technique is also beneficial to the soil, and results in a lower use of synthetic fertilizers.

Vermicompsting units

Vermicomposting units can be set up on many ways. This system can be set up in a large box, a bucket, a bin, a basket and even in a pit in the soil. It is very important to keep in mind that a vermicomposting unit should be more than 1 meters in depth, but may be as long as preferred in width. It is also very important to note that such a unit is set up in the shade. Organic matter that is added to the unit should be dry to prevent an increase of temperature in the unit. The unit should be kept moist, therefore watering is very essential. The amount of materials which are layered during the building of the unit depends on the size of the unit which is set up.
The basic layering in a vermicomposting bin is as following:

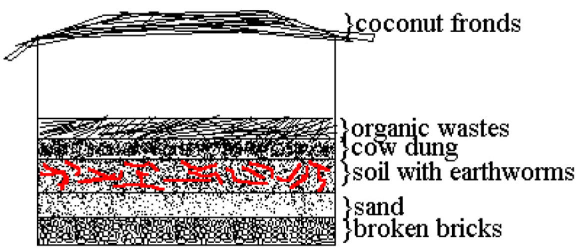

Figure 1. Layering in the vermicomposting unit

The basal layer of the vermi-bed comprises of broken bricks followed by a layer of coarse sand (10 cm thick) in-order to ensure proper drainage. A layer (10 cm) of loamy soil should be placed at the top.100 locally collected earthworms were introduced into the soil. Fresh cattle dung is scattered over the soil and then it was covered with a 10 cm layer of dried grasses. Water is sprinkled on the unit in-order to keep it moist. The dried grasses along with cattle dung is turned once a week. After 60 days, vermicompost units are regularized for the harvesting of vermicompost every 45 days. When the layering is completed, the unit should be covered with dried leaves and left for 60 days. During the period of these 60 days, organic material and cow dung should be added on a weekly basis, while watering every other day, depending on the moisture content of the material in the bin.

Harvesting of vermicompost

Vermicompost should be ready for harvesting in maximum 40-45 days. When the organic material in the unit is changed completely in structure and smells soil like, it is ready for harvest. The compost should be pressed in the hand to check on moisture content. Before harvesting, no water should be added to the unit for 3-4 days and a heap of the compost should be formed in the after harvesting. These actions will derive the earthworms in the deeper layers of the unit where the moisture content is slightly higher. The fourth day, the compost can be harvested and is ready to be used for agricultural purpose. This compost can be used directly in the soil and can be stored for 3 months if disposed well in a plastic bag.

Figure 2. Vermicompost at harvest

Benefits of vermicompost

Vermicompsot has many benefits on the soil, but has also many economic benefits which are:

1. Source of Plant Nutrients to the Soil
    a. Improves its physical structure.
    b. Enriches soil with micro-organisms (adding enzymes such as phosphatase and cellulase)
    c. Microbial activity in worm castings is 10 to 20 times higher than in the soil and organic matter that the worm ingests.
    d. Attracts deep-burrowing earthworms already present in the soil
    e. Improves water holding capacity.
2. Improving Crop Growth and Yield (Plant growth)
    a. Vermicompost plays a major role in improving growth and yield of different field crops, vegetables, and fruit crops.
    b. Enhances germination, plant growth, and crop yield
    c. Improves root growth and structure (rhizosphere)
    d. Enriches soil with micro-organisms (adding plant hormones such as auxins and gibberellic acid)
3. Economic Benefits
    a. Biowastes conversion reduces waste flow to landfills
    b. Elimination of biowastes from the waste stream reduces contamination of other recyclables collected in a single bin (a common problem in communities practicing single-stream recycling).
    c. Boost to rural economy
    d. Less wasteland formation
    e. Low capital investment and relatively simple technologies make vermicomposting practical for less-developed agricultural regions
4. Eco-Friendly Environmental factors
    a. Good quality organic soil additives enhances the water holding capacity and nutrient supplying capacity of soil and also the development of resistance in plants to pests and diseases, thereby providing a sustainable environment in the soil
    b. Wastes create no pollution, as they become valuable raw materials for enhancing soil health
    c. Helps to close the "metabolic gap" through recycling waste on-site
    d. Reduction in greenhouse gas emissions such as methane and nitric oxide (produced in landfills or incinerators when not composted or through methane harvest)

Vermiwash production

Vermiwash is one of the materials produced by Vermicomposting which is an "Eco biotechnological process that transforms energy rich and complex organic substances in to a stabilized vermicomposts" primarily through the action of earthworms but with support of other micro-organisms. Vemiwash contains the soluble nutrients that were released in the vermicomposting process (Nath, *et al*., 2009). Organic fertilizers such as Vermiwash provide a relatively cost effective and safe alternative to chemical fertilizers. According to Ansari and Sukhraj (2010), the use of chemical fertilizers, which is wide spread in many developing countries, can lead to soil damage and reduced soil health and production levels while increasing the incidence of pests and disease and environmental pollution. Vermiwash is a liquid that is obtained when water is left to flow slowely through a vermicomposting like unit. Vermiwash has fertilizing abilities and has also proven to have a pesticidal action when applied as a foliar spray. The layering of a vermiwash bin is the same as a vermicomposting unit, with the exception that this unit consists of a bucket to which a tap is attached at the lowest point to collect the vermiwash when ready. The organic matter that is added to this unit varies from ordinary grass clippings to plant material with pesticidal properties. The organic matter should be dried for 3 to 4 days to accelerate the composting action and regulate the temperature in the bin.

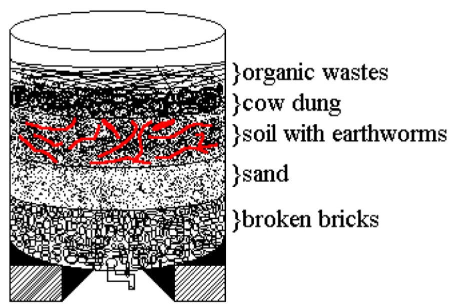

Figure 3. A detailed design of a vermiwash unit

The vermiwash unit is set up using buckets. A tap is fixed on the lower side of each bucket. The bucket is placed on a stand to facilitate collection of vermiwash. 5 cm of broken pebbles are placed at the bottom of the buckets followed by 5 cm layer of coarse sand. Water is then allowed to flow through these layers to enable the settling of the basic filter unit. A 15 cm layer of loamy soil is placed on top of the filter bed. Approximately 300 earthworms are introduced into the soil. Dried grass and cattle dung are placed on top of the soil. The vermiwash unit is left to regularize after 60 days for collection of vermiwash every day. Approximately 0.5 litre can be collected on a daily basis. After layering the different material to the bin, the unit is left for 60 days to regulate with the tap open. Organic matter and cattle dung should be added on a weekly basis as needed. The unit should be watered every other day depending on the moisture content in the bin. Access water should be left to flow through the open tap. Vermiwash will be ready to collect when the liquid that is flowing through the tap gets pale yellow in color. When the color change is seen, the tap should be closed and water should be allowed to drip through the unit overnight. The following day the tap should be opened and the vermiwash should be collected in a plastic container. The color intensity of the vermiwash will differ according to the organic material that is added to the bin. After the first collection, vermiwash can be collected on a daily basis by repeating the same process of adding water to the unit. The vermiwash that is collected can kept stored for 3 months in plastic containers. Vermiwash can be used by a dilution of 10% of the vermiwash with water and spray to the desired plant/crop.

Impact of Organic inputs in the Soil

Organic amendments like vermicompost promote humification, increased microbial activity and enzyme production, which, in turn, increase the aggregate stability of soil particles, resulting in better aeration (Tisdale and Oades, 1982; Dong *et al.*, 1983; Haynes and Swift, 1990; Perucci, 1990). Organic matter has a property of binding mineral particles like calcium, magnesium and potassium in the form of colloids of humus and clay, facilitating stable aggregates of soil particles for desired porosity to sustain plant growth (Haynes, 1986). Soil microbial biomass and enzyme activity are important indicators of soil improvement as a result of addition of organic matter (Perucci, 1990). Apart from these, earthworm castings are reported to contain plant growth promoters, such as auxins and cytokinins (Krishnamoorthy and Vajranabhaiah, 1986). Vermiwash, a liquid fertilizer produced by the action of earthworms, contains soluble plant nutrients, some organic acids, mucus and microbes, that has proved to be effective, both as a biological fertiliser (as a foliar spray) as well as a pesticide (Pramoth, 1995; Ismail, 1997; Kale, 1998).

The high content of organic matter in compost and the resultant effects of the organic matter on the humic fractions and nutrients in soil effectively increase the microbial population, activity and enzyme production, which in turn increases aggregate stability (Tisdale and Oades, 1982; Dong *et al.*, 1983; Haynes and Swift, 1990; Perucci, 1990). Humic acid and fulvic acid are important as persistent binding agents in mineral organic complexes and 52 to 92% of soil organic matter may be involved in these complexes (Edwards and Bremner, 1967; Hamblin, 1977). Increased plant litter incorporation, improved aggregation, better aeration and water relationships and the development of mull characteristics can be observed soils amended with organic inputs. These improvements in soil structure were confirmed by soil morphological studies as illustrated by Rogaar and Boswinkel, (1978). On the contrary there was reduction in organic carbon in plots treated with chemical fertilisers which may be due to negligible organic matter as input, moreover chemical inputs cause degradation of the soil structure resulting in unfavourable conditions for crop growth in an already difficult soil (Pagliai *et al.*, 1983a, b; Shipitalo and Protz, 1988).

Vermicompost, one of the important types of compost, contains earthworm casts that are reported to be higher in available nitrogen (de Vleeschauwer and Lal, 1981; Satchell, 1983) which enhance the activity and number of microorganisms (Stewart and Chaney, 1975; Satchell and Martin, 1984; Satchell *et al.*, 1984). Increase in soil nitrogen through the application of vermicompost is likely to be due to stimulation of microbial activity specifically through increase in the colonization of nitrogen fixers and actinomycetes (Kale 1998; Borken *et al.*, 2002). Much of the effect of application of compost on crop yield and productivity is derived from the plant nutrients, particularly nitrogen in composts (Woodbury, 1992; Maynard, 1993; Ozores-Hampton *et al.*, 1994). Reports indicate that adequate quantities of phosphorus and potassium were supplied by compost application to the soil (Smith, 1992; Maynard, 1993; Ozores-Hampton, *et al.*, 1994). Vermicompost, is reported to contain desired quantity of phosphorus (de Vleeschauwer and Lal, 1981; Satchell, 1983) which enhances the activity and number of microorganisms producing acid-phosphatases in the soil (Stewart and Chaney, 1975; Satchell and Martin, 1984; Satchell *et al.*, 1984). Synergistically, these specific effects appear to raise phosphorus availability in soils amended with vermicompost (Buchanan and Gliessman, 1990).

Vermicompost application in the wheat-paddy cropping system has been reported to increase crop yield (Sharma and Mittra, 1991; Ismail, 1997). This is because nutrients present in vermicompost are readily available to the plants (Ismail, 1995; Rajkhowa *et al.*, 2000). The effect of application of organic amendments like vermicompost on crop yield and production is derived from the plant nutrients, particularly nitrogen (Woodbury, 1992; Maynard, 1993; Ozores-Hampton *et al.*, 1994). Organic phosphorus solublized by microbial activity in composts like the vermicompost is more effective for plant absorption (Mishra and Banger, 1986; Singh *et al.*, 1987). The reduced cost of cultivation, less cost-benefit ratio and higher net income has been recorded in wheat and paddy cultivation through Vermitech compared with the use of chemical fertilisers along with the other economically important crops like peanut (*Archis hypogaea*) and brinjal (*Solanum melongena*) by organic methods (Ismail, 1997). Organic farming has proved to be environment friendly, sustainable and cost effective (Reganold *et al.*, 2001).

Experiments on the effect of earthworms and vermicompost on the cultivation of vegetables like tomato (*Lycopersicum esculentum*), brinjal (*Solanum melongena*) and okra (*Abelmoschus esculentus*) have yielded significant results (Ismail, 1997). Vermicompost as an organic input has been applied to grow vegetables and other crops succesfully (Ismail, 1997). Application of composts like vermicompost could contribute to increased availability of food (Ouédraogo *et al.*, 2001). This is attributed to better growth of plants and higher yield by slow release of nutrients for absorption with additional nutrients like giberellin, cytokinin and auxins, by the application of organic inputs like vermicompost in combination with vermiwash (Raviv *et al.*, 1998; Singh *et al.*, 1998; Subler *et al.*, 1998; Lalitha *et al.*, 2000). The yield of potato and the average weight of potato tubers were significantly higher in plots treated with vermicompost (Table 46). This may be attributed to increased bioavailability of phosphorus by the application of organic amendment in the form of vermicompost (Erich *et al.*, 2002).

Organic manure like vermicompost and vermiwash, when added to soil, augment crop growth and yield (Lalitha *et al.*, 2000). The yields of spinach and onion in response to diluted vermiwash along with vermicompost was highly significant which may be due to increased availability of more exchangeable nutrients in the soil by the application of vermiwash along with vermicompost (Ponomareva, 1950; Finck, 1952; Nijhawan and Kanwar, 1952; Nye, 1955; Atlavinyte and Vanagas, 1973, 1982; Czerwinski *et al.*, 1974; Watanabe, 1975; Cook *et al.*, 1980; Tiwari *et al.*, 1989). Concern about the environment and the economic and social impacts of chemical or conventional agriculture has led to many thinking groups seeking alternative practices that will make agriculture more suitable. Biodynamic farming practices and systems have shown promise in mitigating some of the detrimental effects of chemical-dependent, conventional agriculture on the environment (Reganold *et al.* 1993).

Conclusion

Soils are critical to productivity of both agriculture and natural ecosystems. Soil is an integral system, which is to be maintained through sustainability of nutrient resources. The continuous worldwide soil degradation by erosion, chemicals, acidification and physical abuse requires management in terms of soil quality. The use of organic amendments augmented with Vermitechnology could be adopted as a means for crop production and soil stability. The use of combinations of organic amendments such as vermiwash, and vermicompost can effectively bring about an improvement in soil quality, enhance microbial population and impact crop productivity thereby bringing about long term sustainability. Considering all aspects, such as studies on soil, soil health, yield of crops and cost effectiveness of Vermitechnology as a means of microbial innovation, it is concluded such technology could be applied for sustainable soil enrichment and crop productivity.

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