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Sustainable Agriculture by Vermiculture Biotechnology Using Earthworms

APOORVA GAUR

Vermiculture biotechnology promises to usher in the 'Second Green Revolution' by completely replacing the destructive agro-chemicals which did more harm than good to both the farmers and their farmland. Earthworms restore and improve soil fertility and significantly boost crop productivity. Earthworms excreta (vermicast) is a nutritive 'organic fertilizer' rich in humus, NKP, micronutrients, beneficial soil microbes - 'nitrogen-fixing and phosphate solubilizing bacteria' and 'actinomycets' and growth hormones 'auxins', 'gibberlins' and 'cytokinins'. Both earthworms and its vermicast and body liquid (vermiwash) are scientifically proving as both 'growth promoters and protectors' for crop plants. In the experiments with corn and wheat crops, tomato and egg-plants it displayed excellent growth performances in terms of height of plants, colour and texture of leaves, appearance of flowers and fruits, seed ears etc, as compared to chemical fertilizers and the conventional compost. There is also less incidences of 'pest and disease attack' and 'reduced demand of water' for irrigation in plants grown on vermicompost. Presence of live earthworms in soil also makes significant difference in flower and fruit formation in vegetable crops. Earthworms biomass, a byproduct of VBT is rich in 'high quality protein' and source of nutritive feed materials for fishery, poultry and dairy industries and also for human consumption.

INTRODUCTION

A revolution is unfolding in vermiculture studies for vermicomposting of diverse organic wastes by vermin-culture technology using waste eater earthworms into a nutritive 'organic fertilizer' and using them for production of 'safe food', both in quantity and quality without recourse to agro-chemicals. Heavy use of agro-chemicals since the 'green-revolution' of the 1960's boosted food productivity, with the cost of environment and society. It killed the beneficial soil organisms and destroyed their natural fertility, impaired the power of 'biological resistance' in crops to make them more susceptible to pests and diseases. Chemically grown foods have ad-versely affected human health. The scientific community all over the world is desperately looking for an 'economically viable, socially safe and environmentally sustainable' alternative to the agro-chemicals.

Vermiculture biotechnology promises to usher in the 'Second Green Revolution' by completely replacing the destructive agro-chemicals which did more harm than good to both the farmers and their farmland during the 'First Green Revolution' of the 1950 - 60's. Earthworms restore and improve soil fertility and boost crop productivity by the use of their excreta - 'vermicast'. They excrete beneficial soil microbes, and secrete polysaccha-rides, proteins and other nitrogenous compounds into the soil.

THE CONCEPT OF SUSTAINABLE AGRICULTURE

The new concept of farm production against the destructive 'Chemical Agriculture' has been termed as 'Sustainable Agriculture'. This is about growing 'nutritive and protective foods' with the aid of biological based 'organic fertilizers' without recourse to agro-chemicals. This is thought to be the answer for the 'food safety and security' for the human society in future.

The U.S. National Research Council (1989) defined sustainable agriculture as 'those alternative farming systems and technologies incorporating natural processes, reducing the use of inputs of off-farm sources, ensuring the long term sustainability of current production levels and conserving soil, water, energy and farm biodiversity'. 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.

A POWERFUL GROWTH PROMOTER AND PLANT PROTECTOR

Earthworms vermicompost is a highly nutritive organic fertilizer which is rich in humus, nitrogen (N, 2 - 3%), phosphorus (P, 1.55 - 2.25%), potassium (K, 1.85 -2.25%), micronutrients, beneficial soil microbes like 'nitrogen-fixing bacteria' and mycorrhizal fungi. This organic fertilizer was scientifically proved as miracle plant growth promoters. A matter of still greater agronomic significance is that worms and vermicompost increases biological resistance in plants (due to actinomyctes) and protect them against pest and diseases either by repelling or by suppressing them.

High levels of bio-available nutrients for plants

Earthworms mineralize the nitrogen (N), phosphorus (P), and all essential organic and inorganic elements in the compost to make it bio-available to plants as nutrients . They recycle N in soil in very short time, ranging from 20 - 200 kg N/ha/year and increase nitrogen contents by over 85% . After 28 weeks the soil with living worms contained 75 ppm of nitrate nitrogen (N), compared with the controlled soil which had only 45 ppm . Worms increase nitrogen levels in soil by adding their metabolic and excretory products (vermicast), mucus, body fluid, enzymes and decaying tissues of dead worms. The passage of organic matter through the gut of worm results in phosphorus (P) converted to more bio-available forms.

Humus

Vermicompost contains 'humus' excreted by worms which makes it markedly different from other organic fertilizers. It takes several years for soil or any organic matter to decompose to form humus while earthworms secrete humus in its excreta. Without humus plants cannot grow and survive. The humic and fulvic acids in humus are essential to plants in four basic ways: 1). Enables plant to extract nutrients from soil; 2). Help dissolve unresolved minerals to make organic matter ready for plants to use; 3). Stimulates root growth; and 4). Helps plants overcome stress.

Plant growth hormones

The growth responses of plants from vermicompost appeared more like 'hormone-induced activity' associated with the high levels of nutrients, humic acids and humates in vermicompost. 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.

Soil enzymes

Vermicompost contain enzymes like amylase, lipase, cellulase and chitinase, which continue to break down organic matter in the soil (to release the nutrients and make it available to the plant roots) even after they have been excreted. They also increase the levels of some important soil enzymes like dehydrogenase, acid and alkaline phosphatases and urease. Urease play a key role in N-cycle as it hydrolyses urea and phosphates bioconvert soil phosphorus into bio-available form for plants.

CONTROLLING PEST AND DISEASE WITHOUT PESTICIDES

Earthworms are both 'plant growth promoter and protector'. There has been considerable evidence in recent years regarding the ability of earthworms and its vermicompost to protect plants against various pests and diseases either by suppressing or repelling them or by inducing biological resistance in plants to fight them or by killing them through pesticidal action. Furthermore, the actinomycetes fungus excreted by the earthworms in their vermicast produce chemicals that kill parasitic fungi, such as *Pythium* and *Fusarium.*

Ability to induce biological resistance in plants

Vermicompost contains some antibiotics and actinomycetes which help in increasing the 'power of biological resistance' among the crop plants against pest and diseases. Pesticide spray was significantly reduced where earthworms and vermicompost were used in agriculture.

Ability to repel crop pests

There seems to be strong evidence that worms varmicastings sometimes repel hard-bodied pests populations, and subsequent reduction in plant damage,in tomato, pepper and cabbage trials with 20 and 40% vermicompost additions.

Ability to suppress plant disease

It was reported that vermicompost appli-cation suppressed 20 - 40% infection of insect pests that is, aphids (*Myzus persicae*), mearly bugs (*Pseudococcus spp*.) and cabbage white caterpillars (*Peiris brassicae)* on pepper (*Capiscum annuum*), cabbage (*Brassica oleracea*) and tomato (*Lycopersicum esculentum*). Further it was found that the use of vermicompost in crops inhibited the soil-born fungal diseases. They also found significant suppression of plant-parasitic nematodes in field trials with pepper, tomatoes, strawberries and grapes. The explanation behind this concept is that 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.

Vermiwash - A growth promoting and plant protecting

The brownish-red liquid which collects in all vermcom-posting practices is also 'productive' and 'protective' for farm crops. This liquid partially comes from the body of earthworms (as worm's body contain plenty of water) and is rich in amino acids, vitamins, nutrients like nitrogen, potassium, magnesium, zinc, calcium, iron and copper and some growth hormones like 'auxins', 'cytokinins'. It also contains plenty of nitrogen-fixing and phosphate solubilising bacteria (nitrosomonas, nitrobacter and actinomycetes). Vermiwash has great 'growth promoting' as well as 'pest killing' properties.

Farmers from Bihar in North India reported growth promoting and pesticidal properties of this liquid. They used it on brinjal and tomato with excellent results. The plants were healthy and bore bigger fruits with unique shine over it. Spray of vermiwash effectively controlled all incidences of pests and diseases significantly reduced the use of chemical pesticides and insecticides on vegetable crops and the products were significantly different from others with high market value.

STUDIES ON THE ROLE OF VERMICULTURE BIOTECHNOLOGY

a. It was found that the earthworms (*Aporrectodea trapezoids*) increased growth of wheat crops (*Triticum aestivum*) by 39%, grain yield by 35%, lifted protein value of the grain by 12% and also resisted crop diseases as compared to the control.

b. The studies on the agronomic impacts of vermicompost on rice crops (*Oryza sativa*) reported that greater population of nitrogen fixers, actinomycetes and mycorrhizal fungi inducing better nutrient uptake by crops and better growth.

c. It was also found that worm-worked waste (vermicompost) boosted grape yield by two-fold as compared to chemical fertilizers. Treated vines with vermicompost produced 23% more grapes due to 18% increase in bunch numbers. Furthermore, a study on grapes carried out on 'eroded wastelands' in Sangli district of Maharashtra, India, treated with vermicasting at the rate of 5 tons/ha showed that the grape harvest was normal with improvement in quality, taste and shelf life.

d. The 'yield' of marketable strawberries and the 'weight' of the 'largest fruit' was 35% greater on plants grown on vermicompost as compared to inorganic fertilizers in 220 days after transplanting. Also, there were 36% more 'runners' and 40% more 'flowers' on plants grown on vermicompost. Also, farm soils applied with vermicompost had signifi-cantly greater 'microbial biomass' than the one applied with inorganic fertilizers.

e. Worms and vermicompost promoted excellent growth in the vegetable crop with more flowers and fruits development. But the most significant observation was drastically less incidence of 'Yellow Vein Mosaic', 'Color Rot' and 'Powdery Mildew' diseases in worm and vermicompost applied plants.

f. The presence of earthworms had little effect on herbage production in the first year. But total herbage yield was 25% greater in the second year and 49% greater in the third year in

plots receiving annual topdressing of cattle slurry with earthworms compared to similarly-treated plots with cattle slurry but without earthworms. The conclusion drawn from such study is that earthworms in soil are paramount in plant productivity. In the first year, it took the worm to restore and condition the mined soil. By second year, enough nutritive 'vermicast' got accumulated in soil and improved soil fertility which promoted higher herbage yield (25 %). In the third year, the worm population in soil increased significantly leading to higher excretion of vermicast, higher soil fertility and higher plant production (49%).

g. The farmers at Phaltan in Satara district of Maharashtra, India, applied live earthworms to their sugarcane crop grown on saline soils irrigated by saline ground water. The yield was 125 ton/ha of sugarcane and there was marked improvement in soil chemistry. Within a year, there was 37% more nitrogen, 66% more phosphates and 10% more potash. The chloride content was less by 46%.

EXPERIMENTAL STUDIES TESTIFYING THE VALIDITY OF VERMICULTURE BIOTECHNOLOGY

Farmed wheat crops (Rajendra Agriculture University, India)

This study was made in India under collaborative research program. Cattle dung compost made on farms was used as conventional compost. Vermicompost was also prepared on farm from food and farm wastes including cattle dung. Exclusive application of vermicompost @25 quintal/ha boosted yield 18% higher over the chemical fertilizers. On conventional compost applied @ 100 Q/ha (4 times more than vermicompost) the yield was 17% less than that on vermicompost. The requirement of irrigation was also reduced in vermicompost applied farm plots by 30 - 40%. Test results indicated better availability of essential micronutrients and useful microbes in vermicompost applied soils. Most remarkable was the significantly reduced (nearly 75%) incidences of 'pest and disease attack' on vermicompost grown crops.

ADVANTAGES OF VERMICULTURE BIOTECHNOLOGY IN FARM PRODUCTION

There are several economic and environmental advantages of the use of vermiculture over chemical agriculture in farm production. Besides increasing yield, it produces chemical-free organic foods and also restores the natural fertility of soil over the years. It also significantly reduces the need of water for irrigation and use of chemical pesticides as plants become more resistant to pests and diseases. The cost of food production is also significantly reduced for farmers. It benefits both the 'producers' and the 'consumers' of food.

Can replace destructive chemical fertilizers from farm production

Vermicompost has potential to replace the destructive chemical fertilizers from farm production. It can alone produce food over 30 - 40% higher than those produced by chemical fertilizers. It is at least 75% cheaper than the chemical fertilizers which are produced in factories

from varnishing petroleum products generating huge waste and pollution. Vermicompost is produced from 'waste' which is in plenty all over the world.

Produce nutritive, chemical-free farm products with greater storage value

The biggest advantage of great social significance is that the food produced is completely organic 'safe and chemical-free' and also more 'nutritive'. Use of vermi-compost enhances size, color, smell, taste, flavour and keeping quality (storage value) of flowers, fruits, vegetables and food grains.

Restore natural fertility of farmland soil

Upon successive years of application, vermicompost build-up the soils 'natural fertility' improving its total physical (porous), chemical (rich in nutrients) and biological (beneficial soil microbes) properties. It alsoregenerates a rich population of worms in the farm soil from the cocoons which further help improve soil fertility and subsequently lesser amount of vermicompost is required to maintain a good yield and productivity. On the contrary, with the continued application of chemical fertilizers over the years the 'natural fertility of soil is destroyed' and it becomes 'addict'. Subsequently, greater amount of chemicals are required to maintain the same yield and productivity of previous years.

Reduces water for farm irrigation

Vermicompost has very 'high porosity', 'aeration', 'drain-age' and 'water holding capacity' and thus, its application in soil reduces the requirement of water for irrigation by 30 - 40%.

Kills pests without pesticides

Another big advantage of great social and environmental significance of VBT is that vermicompost 'suppress/ eradicate plant pests and disease' in crops including the soil-born fungal diseases. In field trials with pepper, tomatoes, strawberries and grapes significant sup-pression of plant-parasitic nematodes has been found. There is also significant decrease in arthropods (aphids, buds, mealy bug, and spider mite) populations with 20 and 40% vermicompost additions (Edwards and Arancon, 2004). Humus in vermicast extracts 'toxins', 'harmful fungi and bacteria' from soil and protects plants. Actinomycetes in vermicast induce 'biological resistance' in plants against pests and diseases. As such, use of vermicompost significantly reduces the need for 'chemical pesticides'. These studies indicated over 75%.

EARTHWORM BIOMASS: AS VALUED BY-PRODUCTS OF VBT

In any vermiculture practice, earthworms biomass comes as a valuable by-product and they are good source of nutritive 'worm meal'. They are rich in proteins (65%) with 70 - 80% high quality essential amino acids 'lysine' and 'methionine' and are being used as feed material to

promote 'fishery' and 'poultry' industry and even for manufacture of 'protein food' for human consumption. They are also finding new uses as a source of 'life-saving medicines' for treatment of cardiovascular diseases and some forms of cancer from their enzymes (lumbrokinase) and for production of 'antibiotics' from their ceolomic fluid which has anti-pathogenic properties. The biological compounds from earthworms are also finding new uses as source for production of rubbers, lubricants, cosmetics and detergents. They are all biodegradable and hence environmentally sustainable.

CONCLUSIONS AND REMARKS

Earthworms and its vermicompost works like 'miracle growth promoter' and is nutritionally superior to the conventional compost and chemical fertilizers. Reduced incidence of 'pest and disease attack', and 'better taste of organic food products especially 'fruits and vegetables' grown with vermiculture are matter of great socio-economic and environmental significance. Presence of earthworms in soil particularly makes a big difference in growth of flowering and fruit crops and significantly aid in fruit development. The 18% increase in yield of wheat crops over chemical fertilizers in their farm studies made in India has great economic and agronomic significance.

Use of vermicompost over the years build up the soil's physical, chemical and biological properties restoring its natural fertility. Subsequently, reduced amount of vermi-compost is required to maintain productivity. VBT will truly bring in 'economic prosperity' for the farmers, 'ecological security' for the farms and 'food security' for the people. With the growing global popularity of 'organic foods' which became a US $ 6.5 billion business every year by 2000, there will be great demand for earthworms and vermicompost in future.

The 'natural control of crop pests' influenced by earthworms seems particularly fruitful research area to be pursued. More study is required to develop the potential of 'vermiwash' as a sustainable, non-toxic and environ-mentally friendly alternative to the 'chemical pesticides'. Earthworms are justifying the beliefs and fulfilling the dreams of Charles Darwin who called earthworms as 'friends of farmers' and that of Anatoly Igonin of Russia who said 'Earthworms create soil and improve soil's fertility and provides critical biosphere's functions: disinfecting, neutralizing, protective and productive'.

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