Vermicomposting: New Approach to Modern Agriculture Practices for Sustainable Food Productivity

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Abstract

Vermicomposting is a simple biotechnological process of composting, in which certain species of earthworms are used to enhance the process of waste conversion and produce a better product. Vermicompost is the excreta of earthworm, which are capable of improving soil health and nutrient status. Earthworms excreta (vermicast) has been found to be nutritive organic fertilizer rich in humus, NPK, micronutrients, beneficial soil microbes; nitrogen-fixing, phosphate solubilizing bacteria, actinomycets and growth hormones auxins, gibberlins & cytokinins. Both vermicompost & its body liquid (vermiwash) are proven as good growth promoters & protectors for crop plants.

Keywords: *Vermicompost, Earthworms, Agriculture, Fertilizer, Soil, Organic*

I. INTRODUCTION

A newer branch of biotechnology called 'Vermiculture Technology' is emerging by the use of earthworms to solve various environmental problems from waste management to land (soil) improvement. *Vermes* is a latin word for worms and vermicomposting is basically composting with worms. Vermicomposting is a process in which the biodegradable wastes such as farm wastes, livestock wastes, kitchen wastes, market wastes etc. are converted to nutrient rich vermicompost while passing through the worm-gut. The vermicast (also known as worm cast, worm manure) is a biologically active mound which contains thousands of bacteria, enzymes with plant and animal remnants left undigested by the earthworm. In fact, the bacterial population of a cast has been found to have greater bacterial population than either of ingested soil by the worm. The finished product i.e. the vermicompost colours from dark brown to black. Estimates show that 1 kg earthworms (about 1000 adults) of *eugenics* species would produce 10 kg casts in 60-70 days.

The quality of vermicompost produced from organic waste depends very much on the original material used. Earthworms excreta (vermicast) is similar to humus which is excessively rich nutritive organic fertilizer with NPK, micronutrients like manganese, copper, zinc, cobalt, borax and iron, beneficial soil microbes; nitrogen-fixing, phosphate solubilizing bacteria, actinomycetes and growth hormones auxins, gibberlins & cytokinins. The humus in the cast contains humic acid which serves as binding sites for the plant nutrients but release it as per nutrient requirement of the plant. It helps soil particles to be held as clusters and is believed to aid in prevention of fungal and bacterial plant pathogens. Both vermicompost & its body liquid (vermiwash) are proven to be growth promoters & protectors for crop plants.

Studies have shown that soil amended with vermicompost are found to have significantly greater soil bulk density and hence porous & lighter and never compacted in terms of aeration. In a nut shell, vermicompost improves physical, chemical and biological properties of soil in the long run on repeated application. The concept of vermiculture of organic material with earthworms provides most useful organic manure on one hand and on the other hand it also minimizes the environmental pollution and health hazard [1].

II. EARTHWORM CAST AND VERMICOMPOSTING FOR 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. Use of vermicompost over the years build up the soil's physical, chemical and biological properties restoring its natural fertility. Vermicompost technology for composting of organic wastes is remarkably effective for reduction in the processing time of decomposition and produce good quality compost in terms of nutrients. It is an important component of integrated plant nutrient supply system for balanced fertilization along with maintaining health to sustain the productivity of soils. An important soil restorative management practice is the use of organic manures for crop production. Vermicomposting among other alternatives has been considered as a way to transform these wastes into useful compost for plant and soil, while diminishing their negative environmental impact. Vermicompost is formed from the bio-oxidation and stabilization process of organic material which involves the joint action of earthworms and microorganisms.

Vermicompost is a peat like material with excellent structure, porosity, aeration, drainage and moisture holding capacity [2]. [3] demonstrated that vermicompost is considerably superior to compost with regard to physical and chemical characteristics. Vermicompost is a nutrient-rich, microbiologically-active organic amendment that results from the interactions between earthworms and microorganisms during the breakdown of organic matter. It is a stabilized, finely divided peat-like material with a low C: N ratio, high porosity and high water-holding capacity, in which most nutrients are present in forms that are readily taken up by plants [4] . The most commonly used earthworm species for vermicomposting are Eisenia foetida, Eisenia andrei, Eudrilus eugeniae and Perionyx excavatus. Of these, one of the most promising worms for vermicomposting is Eisenia foetida. The hardy nature of Eisenia sp. worm helps to tolerate wide fluctuation of temperature and humidity. This enables easy culturing of this species. Earthworms due to their casting activities increase water infiltration, facilitate gaseous exchange, improve soil structure and texture, recycle and release nutrients and above all promote plant growth and yield. So, management of earthworm communities in agro ecosystems is highly essential in enhancing the fertility status of soil. Eisenia foetida and Eudrilus euginiae are epigeic species, which are exotic and have been introduced in our country since they are very efficient in conversion of organic waste into manure. Native species like Perionyx excavates and Lampito mauritti (epigeic and anecic species) are also promising and have been successfully exploited for vermiculture and vermicomposting.

Worms swallow large amount of soil with organics everyday and digest them by enzymes. Only 5-10 percent of the digested material is absorbed by them, rest is excreted out in the form of fine mucus coated granular aggregates called ‘vermicastings’ which are rich in NPK, micronutrients and beneficial soil microbes. Researches in vermiculture have revealed that worms can feed upon wide variety of organic wastes and provides sustainable solution for waste management. The farm wastes, animal wastes, garden wastes , the sewage sludge from the municipal wastewater and water treatment plants, the wastewater sludge from paper pulp and cardboard industry, potato and corn chips manufacturing industry, sugarcane industry, and logging offers excellent feed material for vermicomposting by earthworms. Earthworms' action on soil structure is determined by their casts which act on soil aggregates [5]. In general, earthworm casts are more stable in manured soils than in soils without application of organic amendments [6]. Earthworm casts are known to contribute significantly to surface soil fertility in agro ecosystems. They are known to be the sources of plants nutrients. Plants nutrients are generally more concentrated in casts than in their parent soil [7]. Earthworm casts are known to contain enzymes such as proteases, lipases, cellulose, amylases and chitinase that continue to disintegrate the organic matter even after they have been excreted. Earthworm casts consist of masses of mineral soil often mixed with smaller bits of partially digested plant residues. These miniature spherical particles improve soil aeration as they do not pack very close to each other. The roots do not get water logged as it allows excellent drainage in soil. Several studies have been made on the qualitative and quantitative estimate of worm casts in both temperate and tropical regions [8, 9] but reports available from the Indian subcontinent are limited [10, 11, 12]. The physical effects of earthworms on soils result from digging of burrows and production of casts. During the rainy season, their habit of burrowing helps rain water penetration even to the impervious layers of soil. Not all earthworm casts at the soil surface. Majority of lumbricidae species, deposit cast beneath the soil surface, whereas surface casting species are well known among megascolecoid, glossoscolecoid and eudriloid earthworms of the world [9]. Some species cast within their burrows and others on the surface. The form of casting may vary from individual pellets (as in Pheretima posthuma), short threads (as in Perionyx milardi). In some cases, the worms produce a thick and long winding column which produces a hollow mound about 5cm long, 2.5cm wide [13].

Earthworm cast vary in size and shape and are often typical of the same species producing them. It has been observed that casting species of temperate climate generally produces small mound shaped casts [14, 9] but tropical species may deposit much more conspicuous casts [15, 16, 11, and 17]. Textural analysis of worm casts and surrounding soil by [18, 16 & 19] and [20] showed that casts usually contain higher proportions of clay and silt and less sand than the surrounding soil. Vermiculture has application in animal feed industry. Many scientists have reported high levels of nutrients in dried and powdered earthworms [21, 22, 23 & 24]. Earthworm meal has been tested as substitute for animal protein in feeds of poultry, fish and other animals [24, 25]. The combination of nutrients and microbial organisms are essential for growing healthy and productive plants. Vermicompost not only adds microbial organisms and nutrients that have long lasting residual effects, it also modulates structure to the existing soil, increases water retention capacity. Vermicompost may also have significant effects on the soil physical properties. In this sub-tropical country earthworm activity is restricted to rainy and post rainy seasons. During this period, large quantity of earthworm cast is observed on the soil surface. Vermicomposting involves bio-oxidation and stabilization of organic material through the interactions between earthworms and microorganisms. Although microorganisms are mainly responsible for the biochemical degradation of organic matter, earthworm plays an important role in the process by fragmenting and conditioning the substrate, increasing the surface area for growth of microorganisms, and altering its biological activity [4, 26, and 27]. The presence of binding agents from the mucus of earthworms' gut might helped in binding organic and mineral particles together upon gut passage. Thus, it protects the cast from rapid microbial degradation [28]. Earthworm cast of geophagous earthworm; Metaphire tschiliensis tschiliensis contained higher nutrient content, approximately 50% higher organic matter and recorded almost 30% higher in bacterial populations than worm worked soil [29]. Physicochemical properties of the castings of earthworms differ from soil to soil and among different species of earthworms. Earthworm castings are the pool of concentrated nutrients. Previous study had documented higher mineral N, P and S in earthworm casts compared to bulk soil and related the increase with earthworm feeding behaviour [30].

III. RESEARCH METHODOLOGY

Our study aimed on assessing the effect of few chemical fertilizers on selective chemical parameters of the final vermicompost using the Earthworm sp. *Eisneia foetida.*

***Eisenia foetida*:** Earthworms (*E. foetida*) were procured from the vermicomposting unit of Rajasthan College of Agriculture, Udaipur. They were maintained under laboratory conditions and acclimatized for 15 days prior to the experimental set up. Mature worms with well-developed clitellum were used in the experiment.

A. *Exposed Chemical Fertilizers*

1) ***Urea (46% N):***

Inorganic fertilizer Urea in the experiment was buyed from the local market.

2) ***Diammonium Phosphate (DAP):***

Diammonium phosphate (DAP) is the world's most widely used phosphorus (P) fertilizer containing 18 % by weight of NH_4 – N and 46 % by weight of P_2O_5 (water soluble). DAP fertilizer is a good source of P and nitrogen (N) for plant nutrition. It was also purchased from the local market.

3) ***'Kala Sona' (Humic Acid 95%):***

'Kala Sona' is a commercially available brand of unique soil conditioner, a naturally occurring organic substance consisting primarily of humic acid and minor levels of minerals, gypsum and clays.

4) ***'Micro – AD solution'*- '**Micro-AD' is a yield enhancing commercial liquid formulation that contains biostimulants and Biological Macromolecule chelated trace minerals.

B. *Preparations of Worm Beds:*

The experiment was conducted as per method adopted by (Yasmin & D'Souza, 2007). Plastic tubs were used for preparations of soil beds for earthworm. Dried soil (from nearby farmland) was crushed and filtered through a fine mesh sieve. Weighed fine soil was then poured in each plastic tub and water was added to moistened the soil, then 500gm dried powdered cow dung (3 week old) as feeding material of the worm was also added to each plastic tub to avoid starvation thus maintaining soil to cow dung ratio of 1:1.

C. *Addition of chemical fertilizers Urea, Diammonium Phosphate and organic fertilizers Kala Sona & Micro-AD, in Experimental sets*

In our experimental set up the soil bed contained 1 kg of soil and cow dung mixture made in the ratio of 1:1. Three and four doses of Urea and DAP were set respectively, these were 0.75gm/ kg, 1.5gm/ kg, and 2.25gm/ kg and 2.75gm/kg soil. Two doses of each commercial organic fertilizer were also set. In addition to these, one control set without any treatment was also set parallel.

D. *Experimental set-up:*

20 mature earthworms were added to each plastic tub of different dose treatment of the fertilizers in addition to the control set. Three replicates were used for each set to get an average value of each parameter under study. To maintain up-to 70 percent moisture level, water was supplied regularly till the end of experiment. The tubs were covered with wet muslin cloth, so that the essential moisture level needed by the worms is maintained and also it prevented them to crawl out of the tub.

In our study the ingested organic matter was macerated by the earthworms, mixed with inorganic soil particles, passed through the gut and excreted as a cast which subsequently mixed with the soil substrate and was not easily distinguished. Casts were usually found as tiny coherent masses on the surface and also on the side walls of the pots when observed after two weeks and could not be easily separated from the surrounding soil by simple hand sorting thus sieved and analysed.

Table 1.0 Physiochemical Analysis of Vermicast

Parameters	Control	Kala Sona 0.45gm/kg	Kala Sona 0.9gm/kg	Micro -AD 0.2ppm	Micro-AD 0.4ppm	Urea 0.75 gm/kg	Urea 1.5 gm/kg	Urea 2.25 gm/kg	DAP 0.75 gm/kg	DAP 1.5 gm/kg	DAP 2.25 gm/kg	DAP 2.75 gm/kg
pH	7.433 ± 0.058	7.300 ± 0.100	7.033 ± 0.058	7.333 ± 0.058	7.200 ± 0.100	6.200 ± 0.100	5.933 ± 0.115	5.800 ± 0.000	6.667 ± 0.153	6.867 ± 0.115	6.400 ± 0.000	6.167 ± 0.115
Electrical Conductivity	1.060 ± 0.016	1.344 ± 0.012	1.430 ± 0.009	1.760 ± 0.010	1.584 ± 0.008	1.736 ± 0.006	1.952 ± 0.007	1.992 ± 0.010	1.568 ± 0.007	2.006 ± 0.012	2.020 ± 0.020	2.537 ± 0.004
Organic Carbon	8.400 ± 0.265	8.100 ± 0.200	7.840 ± 0.121	7.090 ± 0.110	6.150 ± 0.180	7.700 ± 0.173	6.800 ± 0.098	6.100 ± 0.095	5.320 ± 0.092	7.020 ± 0.171	5.910 ± 0.115	5.850 ± 0.229
Available Nitrogen	0.575 ± 0.010	1.003 ± 0.007	0.880 ± 0.135	0.585 ± 0.006	1.022 ± 0.007	1.245 ± 0.011	1.322 ± 0.008	1.266 ± 0.007	0.963 ± 0.007	1.108 ± 0.007	1.232 ± 0.003	1.216 ± 0.006
Available Phosphorus	0.005 ± 0.001	0.005 ± 0.001	0.004 ± 0.001	0.005 ± 0.001	0.006 ± 0.001	0.005 ± 0.001	0.006 ± 0.001	0.006 ± 0.001	0.010 ± 0.009	0.013 ± 0.001	0.017 ± 0.001	0.019 ± 0.001

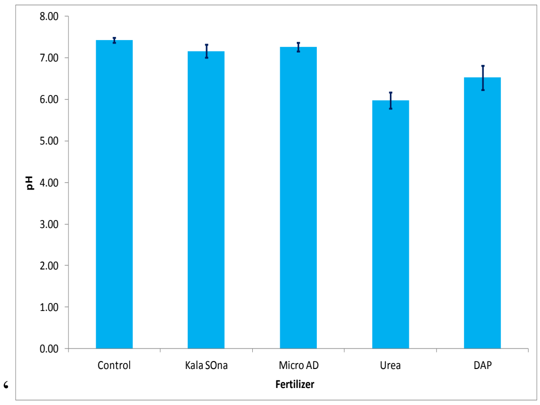

Fig. 1 (a) pH

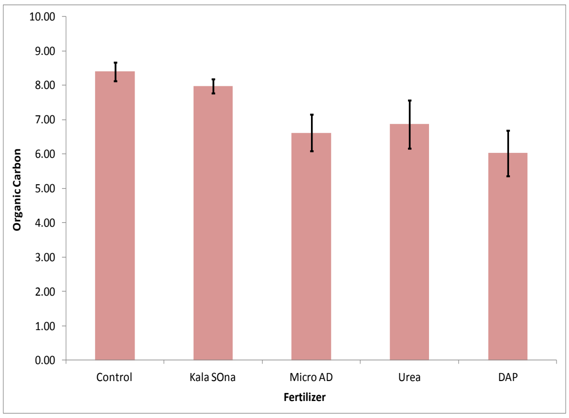

Fig. 1 (c) Organic Carbon

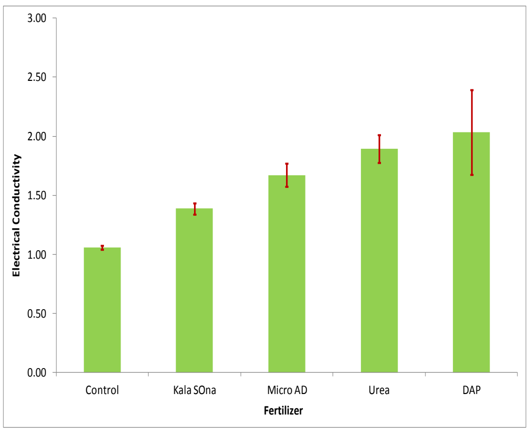

Fig. 1 (b) Electrical Conductivity

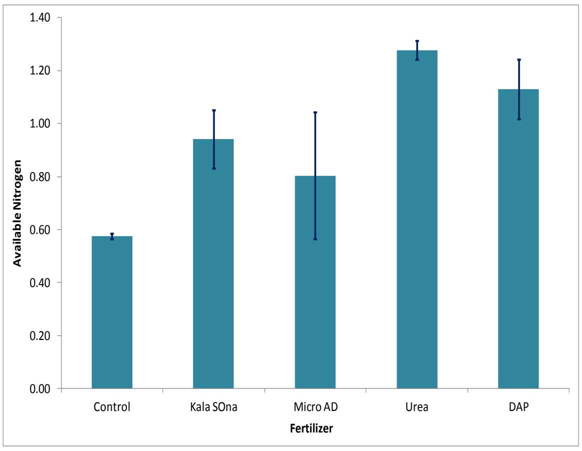

Fig. 1 (d) Available Nitrogen

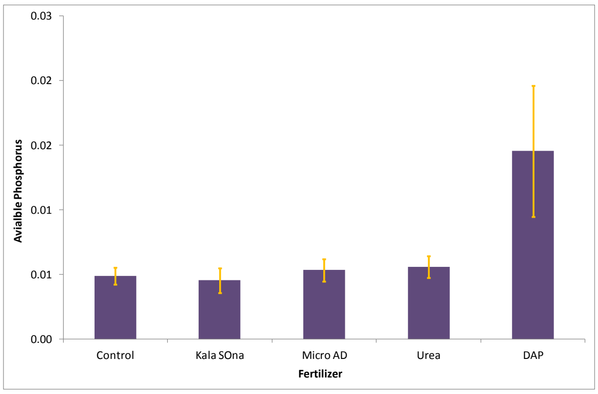

Fig. 1 (e) Available Phosphorus

IV. RESULTS AND DISCUSSION

A. *pH and EC*

pH value of the earthworm cast among control set, fertilizers Kala Sona, Micro-AD, Urea and DAP were analyzed. Anova test result shows highly significant difference in the observed cast pH values of Control, Kala Sona, Micro-AD, Urea and DAP (F=53.64, p<0.001). pH value of the cast was highest for Control and least for Urea set. Electrical conductivity was found to be statistically highly significantly different for control set and different group of fertilizers (F = 16.60, p <0.001). The electrical conductivity of the earthworm cast tested in all the experimental sets was found highest for DAP treated set and minimum for control.

B. *OM, Avl N and Avl P*

Organic matter in the collected earthworm cast was compared among control set, fertilizers Kala Sona, Micro-AD, Urea and DAP. Anova test result shows highly significant difference in the cast organic matter content among them (F=17.10, p<0.001). Organic matter content of worm cast was seen highest in Control whereas it was least for DAP treated set. Available nitrogen content in earthworm cast was compared among in control set, fertilizers Kala Sona, Micro-AD, Urea and DAP. Test result shows highly significant difference in the available nitrogen content among them (F=25.78, p<0.001). Available nitrogen content was highest in Urea treated set which was significantly higher than the amount of available nitrogen in other fertilizers set as well as control group. Available phosphorus in cast analyzed was compared among control set, fertilizers Kala Sona, Micro-AD, Urea and DAP. Test result shows highly significant difference in the available phosphorus among them (F=18.38, p<0.001). Available phosphorus content in the cast was seen highest in DAP treated sets which was significantly higher than the amount of available phosphorus in other fertilizers as well as control group.

Earthworm casts have a higher moisture content, pH, and levels of organic carbon and inorganic nutrients compared to adjacent soil [31, 32 & 33]. The excretory wastes of these worms have been found to contain rich proportions of water soluble nutrients. Due to this reason, incredible results have been obtained in providing increased soil fertility on their use. However, contradictory observations have also been reported on organic carbon and nitrogen [34] and on pH [35] from India. The higher pH of cast soil may be due to the ammonia secreted in the worm's gut, which may act as a neutralizing factor, [36] reported that organic carbon and total nitrogen contents were significantly higher in drillosphere than those of adjacent soil. The decrease in pH values when press mud was treated with E. Eugeniae and Eisenia foetida showed a decreasing trend in pH from 8.6 to 6.7 during vermicomposting over a period of 60 days [37].

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