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Perspective

For Earth's Sake: an Indian Earthworm's Eye View

Sultan Ahmed Ismail*

Ecoscience Research Foundation, Chennai, India

***Corresponding author**
Sultan Ahmed Ismail, Ecoscience Research Foundation, India, Chennai, Email: sultanismail@gmail.com

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Abstract

Among the myriad of soil organisms, earthworms are one of the most vital components of the soil biota in terms of soil formation and maintenance of soil structure and fertility. During feeding, earthworms promote microbial activity by several orders of magnitude, which in turn also accelerate the rates of break down and stabilization of humic fractions or organic matter. Microorganisms are the ultimate decomposers and mineralize in the detritus food chain and in organic matter decomposition. Fresh casts, urine, mucus and coelomic fluid which are rich in the worm-worked soil and burrows act as stimulant for the multiplication of dormant microorganisms in the soil and are responsible for constant release of nutrients into it, which then facilitates root growth and a healthy appropriate sustainable rhizosphere. Generally three species of earthworms have largely been used for vermicomposting, they being *Eisenia fetida*, *Eudrilus eugeniae* and *Perionyx excavatus*; at times *Lumbricus rubellus* and *Lampito mauritii*. The process of composting, although shows the occurrence of different microorganisms such as bacteria, fungi, actinomycetes, phosphate solubilizers and the microorganisms involved in the nitrogen cycle; succession is shown in the quantity of microbes depending upon the nature of the substrate, the age of the compost, the ambience created by the existing microbes to its successors and also the physical and chemical characteristics. Generally microbial population in compost is reported to be Heterotrophic bacteria $463.11 \pm 162.26 \times 10^6$, Fungi $13.46 \pm 2.07 \times 10^4$, and Actinomycetes $44.05 \pm 17.11 \times 10^6$. The density and diversity of algae increase progressively and the maximum is recorded in the vermicompost. Of special significance are the presences of algae such as *Oscillatoria* sp, *Anabaena* sp, and *Nostoc* sp which are known to enhance soil fertility. Most foliar sprays especially the Vermiwash have several components similar to plant growth promoter substances. Studies in our laboratory have revealed the presence of substances which invariably are associated with plant growth. Personal observations and research have indicated that not just addition of organic inputs but the presence of soil biota led by the endemic earthworms in the soil, in fact, enhances the produce in its quantity and quality.

INTRODUCTION

A vast number of organisms engineer a myriad of biochemical changes as decay of organic matter takes place in the soil. Among the organisms, which contribute to soil health, the most important are the earthworms. Based on my continuous research on earthworms made me write "earthworms are the pulse of the soil, healthier the pulse, healthier the soil".

Soil is a living dynamic system whose functions are mediated by diverse living organisms which in agriculture requires proper management and conservation. Unfortunately in today's chemical based agriculture, in the name of the Green Revolution, importance is shown on soil fertility and not on the holistic soil health which provides an integrated sustainable mechanism to the soil to sustain its "living" fabric of nature.

Among the myriad of soil organisms, earthworms are one of the most vital components of the soil biota in terms of soil formation and maintenance of soil structure and fertility. They are extremely important in soil formation, principally through activities in consuming organic matter, fragmenting it and mixing it intimately with mineral particles to form water stable aggregates. During feeding, earthworms promote microbial activity by several orders of magnitude, which in turn accelerate the formation of organic matter as microorganisms are the ultimate decomposers and mineralizes in the detritus food chain and in organic matter decomposition. Fresh casts, urine, mucus and coelomic fluid which are rich in the worm-worked soil and burrows act as stimulant for the multiplication of microorganisms in the soil and are responsible for constant release of nutrients into it, which then facilitates root growth and a sustainable rhizosphere.

Darwin [1], is one of the pioneering workers of modern science on earthworms, though ancient Indian literature has often quoted the benefits of earthworms. As one of few who pioneered in India the culture of local earthworms *Perionyx excavatus* and *Lampito mauritii* and also extensively worked with *Eudrilus eugeniae* after it was introduced by the University of Agriculture Sciences, Hebbal, Bengaluru, into India.

EARTHWORMS

Earthworms belong to the order Chaetopoda under Class Oligochaeta, Phylum Annelida and Division Invertebrata. Indian earthworms mostly are Megascolecids, though Lumbricids also coexist. Several European Lumbricid earthworms found their way into India when the British brought potted plants to their residences especially into the cooler parts of India.

Earthworms are one of the chief components of the soil biota in terms of soil formation and maintenance of soil structure and fertility. They are extremely important in soil formation, principally through activities in consuming organic matter, fragmenting it and mixing it intimately with mineral particles to form water stable aggregates. During feeding, earthworms promote microbial activity by several orders of magnitude, which in turn also accelerate the rates of break down and stabilization of humic fractions or organic matter. Microorganisms are the ultimate decomposers and mineralizers in the detritus food chain and in organic matter decomposition. Earthworms are the facilitators for the dormant microorganisms in soils providing them with organic carbon, optimum temperature, moisture and pH in their gut for their multiplication. Microorganisms are excreted in their casts and also harbored in the drilospheres. Fresh casts, urine, mucus and coelomic fluid which are rich in the worm-worked soil and burrows act as stimulant for the multiplication of dormant microorganisms in the soil and are responsible for constant release of nutrients into it, which then facilitates root growth and a healthy appropriate sustainable rhizosphere.

Though more than 3500 species of earthworms are in the world with India having a little more than 500 species in its diversity, it is easier to recognize earthworms based on their ecological strategies. The surface feeders are the epigeic worms. These worms may or may not consume soil. The Indian blue *Perionyx excavatus*, *P. sansibaricus, Eudrilus eugeniae* and *Eisenia fetida*, belong to the epigeic category.

The anecis or the intermediates are those who create predominantly vertical burrows in the soil. *Lampito mauritii* is an anecic so is *Lumbricus terrestris* in Europe. The endogeics are the predominant horizontal burrowers.

Soils exposed to the veracities of nature and without mulch may not harbor epigeics. The anecic are those who have regained the mastery of aestivation or summer sleep or to overcome the dry spells by migrating and other strategies. A good aerated soil with optimal conditions generally harbors all these three types of earthworms.

A healthy soil (in Indian condition) should at least have 5% organic matter, but conditions presently after the green revolution are poor with a national average of about 0.5%.A good healthy soil generally should have air (about 25%), water (about 25%), organic matter consisting of humus, roots, organisms (about 5%) and mineral matter (about 45%). This enables a large biodiversity of soil organisms as well; enabling soil as a living "organism".The burrows created by the earthworms are called drilospheres though other organisms may also contribute to them. These act as the circulatory and respiratory systems of the soil.

Earthworms used

Generally three species of earthworms have largely been used for vermicomposting, they are *Eisenia fetida, Eudrilus eugeniae* and *Perionyx excavatus*; at times *Lumbricus rubellus* and *Lampito mauritii*. Local species of earthworms used for vermicomposting in India are *Perionyx excavatus* and *Lampito mauritii*.

Succession of microorganisms in the process of composting and the quality of microorganisms in compost and vermicompost:

The process of composting, although shows the occurrence of different microorganisms such as bacteria, fungi, actinomycetes, phosphate solubilizers and the microorganisms involved in the nitrogen cycle; succession is shown in the quantity of microbes depending upon the nature of the substrate, the age of the compost, the ambience created by the existing microbes to its successors and also the physical and chemical characteristics.

The majority of the microorganisms in the initial stages of the composting are the heterotrophic bacteria, which rely on the oxidation of the large amount of organic carbon. It reduces during the thermophilic phase till the formation of the biodung compost. This then increases in the vermicompost due to the passage of the material through the earthworm and the presence of the assimilable C, in the gut and the cast of the earthworms [2].

The role of microorganisms in the nitrogen cycle is very prominent. There is increased presence of ammonifiers in the initial stage of composting, which correlates with the high amount of protein degradation and the microbial contribution to reduce Carbon to Nitrogen (C:N) ratio. Nitrifiers however increase from the initial to the final stages. The products of the ammonifiers create an environment for the multiplication of nitrifiers which utilize ammonia and convert it to nitrite and nitrate. To substantiate this extra-cellular ammonia nitrogen decreases steadily from the initial higher values during the entire composting process. The ammonification process is reported to increase due to high temperature [3].

Nitrification potential as indicated by Nitrite Nitrogen (NO_2-N) decreases with composting time [4]. The NO_2 production drops and stabilizes to low levels during the later stages of composting till no further decomposition can take place, as the C:N ratio gets stabilized [4].

The Nitrate (NO_3) production, according to our observation [5], increases till about the 14th day of composting thereafter declining till the 35th day. This drop could be due to high temperature, as nitrification is inhibited by high temperature and could also indicate microbial immobilization. The dominance of the extra-cellular production of NO_3 on the worm worked vermicompost could be the result of enhanced nitrifier activity.

Amount of phosphate in compost samples throughout the process and vermicompost records a steady increase from the initial phase of composting till vermicompost production [5]. This is due to the increased phosphatase activity in vermicompost as earthworm casts and feces exhibit higher phosphatase activity [6]. Phosphate solubilizers also steadily increase throughout the process. So in terms of succession ammonifiers which are the major organic N decomposers are succeeded by the nitrifiers and phosphate solubilizers.

Oxidation of sulfur and sulfate compounds is elaborated by aerobic obligate autotrophs. *Thiobacillus thiooxidans* and *Thiobacillus thioparus*, recorded in vermicompost attribute to the reason for vermicompost being capable of ameliorating sodic soils. The population density of the actinomycetes increases from the initial phase of composting till the maturation phase except for a period of decline in the thermophilic phase.

Actinomycetes occur after readily available substrate disappears in the early stages and colonize in the humification stage as the compost reaches maturity. It is also found that the optimum temperature of actinomycetes is 40-50°C, which is also the temperature for lignin degradation in compost [7].

Fungal density decreases as the composting process progresses. Mucoraceous group of fungi commonly referred to as sugar fungi are observed in the initial and early phases of composting.Species of Aspergillus dominate and are responsible for major degradation of initial organic carbon as they are known to elaborate cellullases and hemicellulases. A lignolytic fungus *Coprinus* sp is predominantly found to colonize the compost only towards the end when complex organic matter is biodegraded.

The thermophilic fungi record an increase in density and diversity during the thermophilic phase and these are known to bring about degradation of cellulose, lignin and pectin at a faster rate in conjunction with high temperature. The presence of *Trichoderma viridae* and *Trichoderma harzianum*, both potential biocontrol agents, during the composting process and to a larger magnitude in the vermicompost is noteworthy.

The density and diversity of algae increase progressively and maximum is recorded in the vermicompost. Of special significance are the presences of algae such as *Oscillatoria* sp, *Anabaena* sp, and *Nostoc* sp which are known to enhance soil fertility.

For information of those using earthworms or desirous of using compost/vermicompost/in-situ composting the material generally has the following micro organisms [5,8].

Generally microbial population in compost is reported to be

Heterotrophic bacteria 463.11 ± 162.26 X 10^6

Fungi population 13.46 ± 2.07X10^4

Actinomycetes 44.05 ± 17.11 X 10^6

Common bacteria in vermicompost

Bacillus sp

Pseudomonas sp

Serratia sp

Klebsiella sp

Enterobacter sp

Common fungi in vermicompost

Absidia sp

Rhizopus stolonifer

Aspergillus flavus

A. fumigatus

Aspergillus flavipes

A. nidulans

A. niger

A. ochraceus

A. tamarii

Chrysosporium pannorum

Emericella nidulans

Dreschslera australiensis

Fusarium oxysporum

Monilia sitophila

Penicillium citrinum

P. oxalicum

Mucorracemosus

Trichoderma viride

Algae:

Cladophora sp

Oscillatoria sp

Anabaena anomala

Anabaena ambigua

Arthrospira sp

Westiellopsis prolifiea

Nostoc sp

Protococcus sp

Cladophora sp

Schizothrix sp

Chaetonema sp

Stigonema sp

Though we have identified presence of actinomycetes in earthworm casts in our laboratory, researchers from other laboratories have identified species of actinomycetes in castings [9]. Association of actinomycetes confers many advantages to plants like production of antibiotics, extracellular enzymes, phytohormones, siderophores and phosphate solubilization, protects plant against biotic and abiotic stress.

Common actinomycetes in vermicompost

Streptomyces

Streptosporangium

Saccharoploys pora

Actinomadura

Nocardia

Nocardiopsis

Planobispora

Micromonospora

Actinomadura

Microbispora

Thermobifida

One of their excellent tools in Biodynamic farming is biodynamic chromatography. We have applied this on analysis of composts from several sources and have been a good functional tool. This technique did reveal that the vermicompost prepared by the endemic (local) earthworms' *P. excavatus* and *L. mauritii* which we call as vermitech is indeed superior to that produced by exotic compost producing earthworms [8].

Vermiwash is one such excellent liquid fertiliser [10]. Studies in our laboratory by Sheik Ali [11], have revealed the presence of substances (Table 1) which invariably are associated with plant growth. There are about 3 isomers of indole compounds separated in Vermiwash, 2-(4-methylphenyl) indolizine is an alkaloid which has a significant role in plant growth promotion. At retention time of 19.70 min capric acid was separated, which is a fatty acid, obtained from the castings of earthworms which is also reported to have a significant role in plant growth promotion in lower concentrations [12]. Maleic acid which was identified is a well established plant growth promoter [13]. Methyl 2-4 (tert-butylphenoxy) acetate belongs to the ring-substituted phenoxy aliphatic acids generally exhibiting a strong retarding effect on abscission in turn promote plant growth. Vermiwash by its instinctive quality might probably promote humification, increased microbial activity to produce the plant growth promoting compounds and enzyme production [14]. All the compounds present in vermiwash may not individually help in plant growth but perhaps act synergistically along with the beneficial soil microbes found in vermiwash.

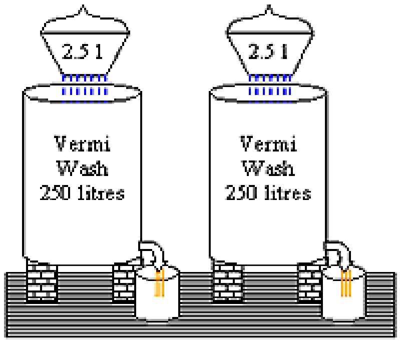
Experiments applying Vermiwash with Panjagavya, etc by Thangaraj [15], on plants and their chromosomes have shown significant results of enhanced xylem vessels and no chromosomal damage.Moreover these can be prepared by farmers in their farms.

In organic farming practice we do not nurse the plant, we nurse the soil. The soil in turn promotes its group of biotic elements who churn the nutrients as desired by the plant.Phytonutrients, such as polyphenols and antioxidants, protect both people and plants. Several insecticides, herbicides, and fungicides actually block a plant's ability to manufacture these important plant compounds. Most changes in agricultural technology especially after the green revolution have ecological effects on soil organisms that can affect higher plants and animals, including man. Concentrating just on productivity has robbed human care for the soil and its biota.

VERMIWASH

Worm worked soils have burrows formed by the earthworms. Bacteria richly inhabit these burrows, also called as the drilospheres. Water passing through these passages washes the nutrients from these burrows to the roots to be absorbed by the plants. This principle is applied in the preparation of vermiwash. Vermiwash is a very good foliar spray.

Vermiwash units can be set up either in barrels or in buckets or even in small earthen pots. It is the principle that is important. The procedure explained here is for setting up of a 250 Liter barrel. An empty barrel with one side open is taken. On the other side, a hole is made to accommodate the vertical limb of a 'T' jointed tube in a way that about half to one inch of the tube projects into the barrel. To one end of the horizontal limb is attached a tap. The other end is kept closed. This serves as an emergency opening to clean the 'T' jointed tube if it gets clogged.



Setting up of a vermiwash unit

The entire unit is set up on a short pedestal made of few bricks to facilitate easy collection of vermiwash. Keeping the tap open, a 25 cm layer of broken bricks or pebbles is placed. A 25 cm layer of coarse sand then follows the layer of bricks. Water is then made to flow through these layers to enable the setting up of the basic filter unit. On top of this layer is placed a 30 to 45 cm layer of loamy soil. It is moistened and into this is introduced about 50 numbers each of the surface (epigeic) and sub-surface (anecic) earthworms. Cattle dung pats and hay is placed on top of the soil layer and gently moistened. The tap is kept open for the next 15 days. Water is added every day to keep the unit moist.

On the 16th day, the tap is closed and on top of the unit a metal container or mud pot perforated at the base as a sprinkler is suspended. 5 litres of water (the volume of water taken in this container is one fiftieth of the size of the main container) is poured into this container and allowed to gradually sprinkle on the barrel overnight. This water percolates through the compost, the burrows of the earthworms and gets collected at the base. The tap of the unit is opened the next day morning and the vermiwash is collected. The tap is then closed and the suspended pot is refilled with 5 litres of water that evening to be collected again the following morning. Cowdung pats and hay may be replaced periodically based on need. The entire set up may be emptied and reset between 10 and 12 months of use. Vermiwash

Table 1: Components of Vermiwash.

No	Compound	GC Retention Time (min)	Chemical Formula	CAS registry Number	Molecular Weight (g/mol)
1	2- (4-methyl phenyl) indolizine	19.33	$C_{15}H_{13}N$	7496-81-3	207.27
2	Decanoic acid, ethyl ester	19.70	$C_{12}H_{24}O_2$	110-38-3	200.318
3	1-methyl-2-phenyl-indole	27.10	$C_{15}H_{13}N$	3558-24-5	207.27
4	2-methyl-7-phenyl-1H-indole	29.83	$C_{15}H_{13}N$	1140-08-5	207.27
5	Pentadioic acid, dihydrazide N2,N2'-bis(2-furfurylideno)*	31.16	$C_{15}H_{16}N_4O_4$	324012-36-4	316.312
6	Methyl 2-(4-tert-butyl phenoxy) acetate*	33.44	$C_{13}H_{18}O_3$	88530-52-3	222.28

is diluted with water (10%) before spraying. This has been found to be very effective on several plants.

Healthy soils support healthy produce. Personal observations and research have indicated that not just addition of organic inputs but the presence of soil biota in the soil, in fact, enhances the produce in its quantity and quality. Thus it is very much confirmed that "earthworms are the pulse of the soil, healthier the pulse, healthier the soil".

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