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A Review-Vermicomposting: An Effective option for Agriculture Waste Management

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ABSTRACT: Green revolution increases food production to satisfy consumption rate by adopting improved varieties, high fertiliser dose and irrigation etc. Crop production increases the food-grain as well as biological yield. Rice wheat and sugarcane contribute in high residue generation due to more crop residue generation on and creates difficulty in off-farm management. Due to their high C:N ratio mineralisation process slows down and sowing of crop on standing residue will affect germination and plant stand. Since farmers need quick land preparation for the next crop sowing, they will burn the crop residue, which creates environmental pollution, health hazards, loss of organic matter and loss of essential plant nutrients. Hence collection of crop residue and utilisation in same farm by production of compost is best alternative and eco-friendly method of residue management. Among different types of composting, Vermicompost is best method as it is an eco-biotechnological process to manage agricultural/biodegradable waste by utilisation of earthworms and finally convert biodegradable waste into organic fertiliser. Vermicast is by product of vermicompost which is rich in nutrients, humus, beneficial soil microorganisms like- nitrogen fixer, PSB and actinimycets, and growth promoters like- Auxins, GA_3, cytokinin which are suitable alternative to chemical fertilisers. It needs less time to production, quick response to plants and increases, water holding capacity, reduces BD. It acts as media to many nursery plants.

Keywords: residue burning, pollution, vermicast, humus, beneficial soil microbes, growth promoters

INTRODUCTION

In agriculture, after separation of economical part of crop after harvesting and threshing of crops the large amount of biological yield neglected and left over the field as waste. Crop residue, weeds, undesired plant parts, leaf litter, bedding materials of animal, crop and livestock by-products are said to be agriculture waste. As per Hiloidhari *et al*., (2014) and Jain *et al*. (2014) residue generation of India is 620 to 680 MT, out of which one third of crop residue is not utilised (234 MT) and among which 30% of residue is related to rice and wheat. Major crop residue generated from cereals, pulses, oilseeds and sugarcane which contributes 545 MT and remaining is being contributed from fibre crops like- jute and cotton (80 MT), horticultural crops (banana, coconut and areca nut61 MT). Cereals contribute 368 MT and holds 1st position in residue generation followed by 111 MT from sugarcane.

Crop residue generation is mainly depending on types of crops grown, cropping intensity and their productivity in different states of the country. Among all the state, Uttar Pradesh got 1st position in crop residue generation per year contributing 116 MT followed by West Bengal (63.26 MT) and Andra Pradesh (57.44 MT). Even Uttar Pradesh is 1stin position in residue generation from cereals and sugarcane (72.03 MT and 41.13 MT, respectively), Gujarat leading in fibre crops residue generation contributes 28.62 MT and Rajasthan dominates Oilseeds residue (9.26 MT)(Singh *et al*., 2019).

In Indo-Gangetic plains, about 69% of generated crop residue is burnt in field and remaining 31% contributed from non-agricultural sector (Singh *et al*., 2019). Rice-wheat cropping system contributes 84% and remaining cropping system contributes 16% of crop residue burnt in the field and 62% is contributed from rice and wheat crop. Burning of crop residue not only creates environmental problem but also human and animal health hazards, loss of essential nutrient and reduced organic carbon. Burning of one ton of crop residue releases 1,515 Kg CO_2, 92 kg CO, 3.83 kg NO_2, 0.4 kg SO_2, 2.7 kg CH_4, and 15.7 kg non-methane volatile organic compounds (Bakker *et al*., 2013 ; IARI, 2012; Singh *et al*., 2008). About 90% of N, S and 15-20% of phosphorus and potassium present in paddy residue are lost during the burning. It also creates health issues like breathing problem, Confusion, light headedness, and flu effects, chest tightness, Asthma, eyes are irritation, finally leads to heart and lung damage.

Burning is not a good practice to manage agricultural waste, instead of burning, residue can be utilised in-situ (mulching and incorporation) and off farm utilisation like electricity generation, as raw material in brick kilns, fruits and vegetable packaging, compost making etc. Composting is easy way, low cost/zero cost to produce nutrient rich bulky organic manure. Composting has major role in organically growing crops which supplies nutrients by reducing the toxicants present in the crop residue. Instead of direct utilisation of crop residue in the field, processed compost can be used which has low C/N ratio. Vermicomposting is good method of composting by converting waste to wealth in less time as compared to other composting methods. It is a process of producing compost by utilizing earthworms to turn the organic waste/crop residue into high nutrient and quality compost that consists mainly of worm excreta in addition to decayed organic matter (Ismail 2005; Deviand Prakash 2015). It helps to convert organic waste like agro-waste, animal manure, litter and domestic refuse into high nutrient fertiliser for soil and plants (Gajalakshmi and Abassi 2004). Vermicompost is good for developing sustainable agriculture and balancing ecosystem. This review paper mainly focuses the following points.

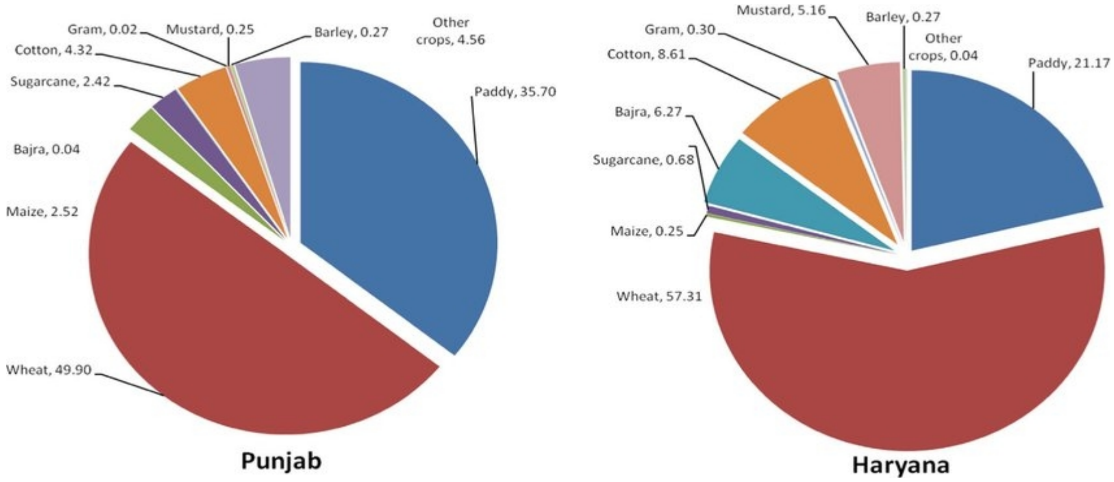


Fig. 1. Crop residue generation from different crops grown in IGP of Haryana and Punjab (Lohan *et al*., 2018)

A. Role of earthworms in Vermicomposting

Vermicompost is a method of making compost fromutilisation of biogegradable waste materials by earthworms which are present in moist soil. The earthworms eat the waste materials, passes it through their digestive system and passed out as excreta which is a final product and called as vermicompost. It is an organic rich fertilizer which contains humus, N, P and K, micronutrients, beneficial soil microbes (Bacteria, Fungus, Actinomycetes, Diazotropes etc.), nitrogen fixing and phosphate solubilising bacteria, growth hormones (auxins, gibberellins, cytokinines) (Sinha *et al*. 2011; Chauhan and Singh 2015) and it is suitable alternatives to chemical fertilizers and act as growth promoter and protector for crop plants and it also improves soil physical, chemical and biological properties (Ansari and Jaikishun 2011; Chauhan and Singh 2013). Under controlled condition, scientific breeding of earthworms is called Vermiculture. Similarly, combination of vermiculture and vermicomposting is called Vermitechnology. The earthworms are main soil macrofauna which helps in soil bio-geochemical process, and it alters soil physical, chemical and biological properties by utilising residue. The earthworms proximate activities improves the carbon and nitrogen mineralisation of respective substrates which is significantly influenced by earthworms population. Similarly, microorganisms play role in biochemical degradation of complex substrate so that with the help of earthworms fragmenting and conditioning of residue fastens. Residue fragmentation by earthworm increases surface area of residue which is easy to degrade by microbes. Earthworms are mainly used for following purposes.

- To create barren to arable soil, decomposition of organic residue, facilitating good aeration and drainage.
- Enriched and easily vaialable fertilizer i.e.vermi-fertilizer and worm tissue (used as animal feed).
- Ecological balance, maintaining soil fertility, reducing heavy metal toxicity.

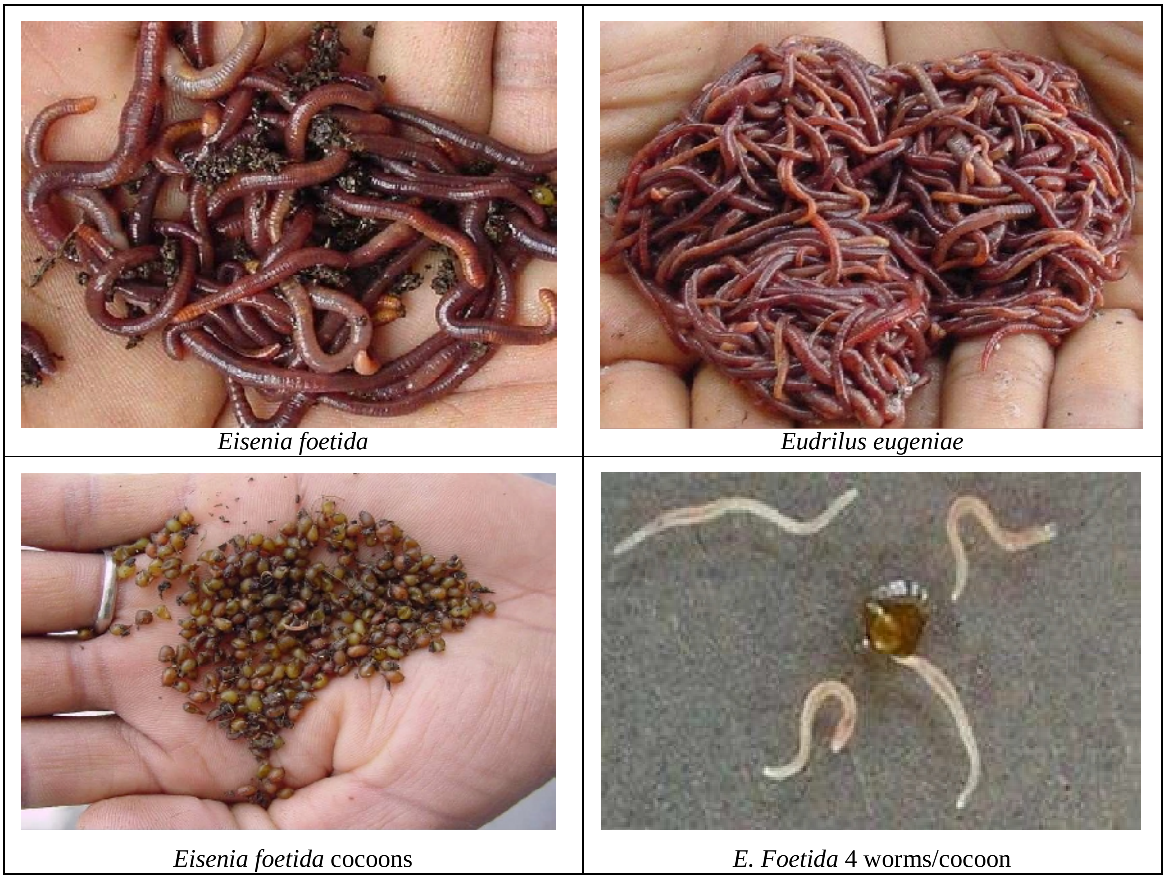
Table 1: Nutrient content of Vermicompost.

Sr. No.	Nutrient	Content (%)
1	OC (organic carbon)	9.15-17.98
2	Total N	1.5-2.10
3	Total P	1-1.5
4	Total K	0.60
5	Ca and Mg	22-70 meq/100g of soil
6	S	128-548 ppm
7	Cu	100 ppm
8	Fe	1800 ppm
9	Zn	50 ppm

B. Types of earthworms

Earthworms phyllum Annelida of Animal Kingdom which are long and cylindrical shape and having large grooves. Around 3000 earthworm spp. are present in world which are adopted in varied climatic conditions. Among them more than 300 worms are identified in the country. At least two hermophrodite earthworms required for propagation. In egg laying stage the clitellum is transformed in hard like capsule are said to be cocoons. Cocoons range may vary from 1-5 and few of them survive hatch. Next juveniles will take 50 to 60 days for formation of cocoons. The average worms lifespan is 1 to 10 years under good environmental conditions.

Surface feeding earthworms are more important in vermicomposting, which are said to be epigeic worms ex- *Eudrilus eugeniae* and *Eisenia foetida* these are exotic worms and *Perionix excavates* is native to India. These worms feed on leaf litter and upper soil and *Lampito mauritti* is an indigenous worm species which feeds in-situ crop residue and organic matter. These group worms are shorter and have slender body with colour varying from red to darker brown colour. These worms have efficient capacity of recycling organic materials. Most prominent species are *Eudrilus eugeniae* and *Eisenia foetida* because of their potentialde composition capacity of organic wastes, wide range adaptability i.e., 0-40°C with the optimum temperature of 20-30°C.



Eisenia foetida | *Eudrilus eugeniae* | *Eisenia foetida* cocoons | *E. Foetida* 4 worms/cocoon

Fig. 2. Commonly using earthworm spp.

C. Mechanism of vermicomposting

Physical breakdown of waste materials from the earthworms which are passed through gizzards reduces its size and attains less than 2 micron which gives fragment and conditioning to materials and increasing surface area which is helpful for microbial development and altering soil physical, chemical and biological activity. These materials are exposed to certain enzymatic activity i.e. protease, lipase, amylase, cellulose and chitinase secreted by worms gutt at the time of residue passing into it and are responsible for microbial decomposition activity. These enzymes are mainly helpful in breakdown of complex biomolecule to simple compound (Bajal *et al*., 2019). Worms utilises only 5 to 10% consumed materials for their growth and development and rest is passed as cast. Excretory substances such as urea and ammonia are secreted from guts of worms act as readily available nutrient pool which can supply nutrients to microorganisms for their structural stability.

D. Vermicompost preparation

Carbon-nitrogen ratio may vary from different crop residue, and this is the main parameter for residue decomposition mediated with microorganism. If the C/N ratio of crop residue is more, the microbes suffers nitrogen supply for their development and they can utilise the N from soil which in turn creates acute nitrogen deficieny at initial stage, however it is recovered in the later stages. Some of the crop residue and their C/N ratios are listed in Table 2. (Kale 1998; Gupta and Garg 2008; Suthar 2008, 2009; Solis-Mejia *et al.* 2012). Sometimes, the C/N ratios reaches to less than 20:1 (Senesi, 1989) it is due to rapid decomposition of organic waste and mineralisation and stabilisation during the period of vermicomposting (Kaushik and Garg, 2003).

For preparation of vermicompost, following materials is required:

Raw materials required: Any organic material generated in the farm like bhusa, leaf fall, weed biomass, dry leaves or residue collected from field, sand/soil, biodegradable materials from kitchen and field etc. Due to the risk of Tetanus virus from Horse dung, it is lethal to humans, that's why it is not used in earthworm feed. Marigold, Paddy husk and pine needles are also not used in the pit as they cause harm to earthworms and humans at harvesting time.

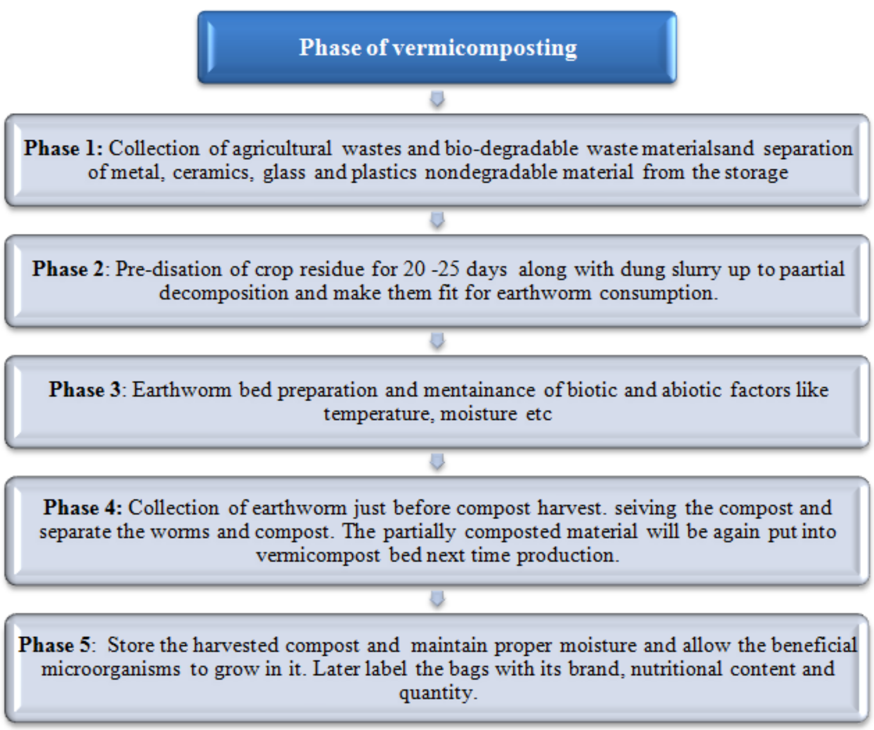
Starter: Cow dung, Biogas slurry, or urine of cattle

Soil animal: different cultivable earth worms, their characters and benefits are listed in Table 3.

Thatched roof/vermished.

Table 2: C/N ratio of crop residue (source: nrcs.usda.gov).

Sr. No.	Crop	C:N ratio
1	Rye Straw	82:1
2	Paddy straw	86:1
3	Sugarcane straw	80-100:1
4	Wheat straw	80:1
5	Oat straw	70:1
6	Corn Stover	57:1
7	Rye as cover crop	37:1
8	Pea straw	29:1
9	Rye Cover Crop (Vegetative)	26:1
10	Alfalfa straw	25:1
11	Flax straw	55:1
12	Sunflower stover	60:1
13	Soybean residue	65:1
14	Potato vines	31:1
15	Mustard	33:1



Methods:

- **Bed Method:**
- Make floor bed with size 6×2×2 feet and fill the organic waste.
- This method is easy to maintain moisture temperature and humidity

- **Pit method:**
- Make cemented pits with a dimention of 5×5×3 feet. pit is covered with hard materials at initial.
- Commonly this method is not preperd due to water stagnation and poor aeration.

Steps involved in Vermicompost preparation

Compost can be prepared by pit, bed, or heap methods. The suitable dimension for pit method of compost pit is 10× 4×2 feets. The length and width can be increased or decreased depending on raw material availability. But the height of pit should be maintained at 2 feet as most of the worms activity occurs in this depth only. Preparation site should be selected in barren and uncultivable land and the land should not be suitable for any economic product, should be covered with trees for shade, and site should be near to water source.

- Cow dung and chopped dry leaf should be mixed well in the proportion of 3:1 ratio
- Thin layer of 15 to 20 cm chopped layer, hard cereal crop residue (maize, sorghum etc.), grasses as bedding material
- Beds of partial decomposed materials of size 6×2×2 feet
- Each bed should contain 0.5 to 1.0 q raw materials which contains cereal crop, pulses and any other crop residues.
- After addition of bedding materials, 1st and 2nd layer should be watered and covered with cow dung of 2 in at every layer. Continue the layering up to the ground level in pit method and up to 2 feet above ground level in heap method. Maintain proper moisture and temperature by turning the crop residue.
- Leave the crop residue to partial decomposition for 20-25 days.
- After 24th day of introduction of earthworms, (1500-2000 number) depending on pit capacity (2000 worms in 1 m^2), should be released on upper layer of bed
- sprinkle the water immediately after release of earthworms.
- maintain moisture, temperature and humidity and the bedding materials should be turned once after 30 days.
- compost gets ready to harvest after 45 to 50 days from partial decomposed material, depending on climate and usually two to three months of total duration will be taken from beginning to the harvest of compost.
- The turnover of the compost is 75% means if 1000kg of raw materials are used in pit, the turn out will be 750 kg.

E. Favourable conditions and factors affecting earthworm distribution

Distribution of worms in soil layer or construction unit mainly depends on pH, EC, organic matter, temperature, moisture etc. (Edwords and Bohlen, 1996).

- Temperature: Temperature helps in worms' activity like metabolism, respiration regulation of body temperature. So, it should be maintained between 18°C to 35°C (Edwards and Burrows, 1988 and Benitez *et al*., 1999).
- pH and Electrical conductivity: it determine the distribution and abundance of earthworms and are sensitive to hydrogen ion concentration. Most of the earthworm spp. requires neutral pH (Singh 1997; Narayan, 2000; Pagaria and Totwat 2007; Suthar 2008; Panday and Yadav, 2009). A positive correlation is found between seasonal abundance of juveniles and adults and pH (Reddy and Pasha, 1993). Electrical conductivity is mainly depending on freely available minerals and ion generated during excretion by the earthworms (Garg *et al.*

2006) and raw material used for vermicomposting (Atiyeh *et al.* 2002). Increase of EC in pit is due to loss of weight of organic matter by decomposition and release of different salts in available form (Wong *et al.* 1997; Kaviraj and Sharma 2003; Nath *et al.* 2009).

- Moisture: it is the main components of earthworm body and around 75-90% of the body weight is covered by water (Ansari and Ismail, 2012). However, under adverse situation they move to deeper layer to stay moistened. Moisture also influences number and biomass of earthworm. So, moisture management is important in pit which should be maintained at 60-70%, moisture above or below this range may increases the mortality rate of worms.
- Aeration and soil texture: the 50% of aeration should be maintained from total pore space. If it is less than required amount, the worms may feel suffocation which leads to death of worms. Soil texture influences earthworm populations due to moisture holding capacity, nutrient content and CEC.

F. Compost harvest from pit

Before one week of harvesting, stop application of water to the pit. Worms spread over the pit depth and some are forms boll like structure and present at top layer are collected and separate the worms by adding it into bucket of water. The worms are suspended in bucket of water and they easily in water which makes easy to collect them, and most of the worms settle down at lower surface of the pit because of continuous disturbance of topsoil. Hence, first collect the top compost and deeper layer should be sieved with 2 mm sieve and separately collect the worms and compost. Remaining undecomposed materials are transferred to other pit for composting again. After sieving, collect the compost and place in proper shady place and maintain their moisture level and this final product is called as Vermicompost.

Pack the compost into proper bagging materials like plastic or gunny bags for the purpose of marketing. Recomposting can be done in the same pit after the compost harvest or can be done in another pit. Even composting can be done in field condition by application of 5 ton of vermicompost and some worms into field along with application of crop residue and left overs in the field and apply irrigation in 15 days intervals.

Fig. 2. Sieving, Packing and labelling of Vermicompost.

Precautions

Do not use plastic materials to cover the Vermicompost pit because it traps heat and gases released during decomposition process instead of this go for coconut leaves or paddy straw over the pit. Don't go for overloading in heap as it creates heat in unit and reduces aeration which finally may affect worms population. Do not keep the pit dry because worms get away from dry place and move towards moistened area. Excessive water creates water logging and harms the worms and leads to mortality. Watering is suggested daily in summer and once in every three days in rainy and winter season. Avoid application of acid rich materials like tomato and citrus wastes as it may reduces worms density. In rainy condition, drainage channel is necessary in heap method for avoiding water stagnation. Organic wastes should be free from non-biodegradable materials like- glass, plastic, stone, toxic materials, ceramics etc.

Live worms transportation:

Transportation of worms is done in cardboard or plastic container which should be well aerated and contain feeding material for worms. Feeding material of 0.5 to 1.5 g is required per worm in one day. The container should involve cocoons, juveniles and adults because sometimes juvenile and adults find difficult to adopt to new climatic conditions and more chances of death of worms may occur, in this situation cocoons may help their population density increment in new area.

Natural enemies and their management in pit

Ant, centipedes, termites, pigs, rat, birds, snake etc are natural enemies in pit. At the time of pit filling go for 4% neem cake application to easily reduce the natural enemies' population.

Compost application rate in different crops:

Vermicompost can be applied to any crop and at any duration of crop but under large scale application, it should be mixed with soil by broadcasting. So it will well aggregates with soil particle and releases nutrient in it.

- Field crops requires 5 to 6 t/ha
- Vegetables required 10-12t/ha
- Flowering plants required 100 to 200 g per plant or per square feet area.
- Fruit trees needs 5 to 10 kg per tree

Advantages of Vermicompost

1. Vermicompost is a rich source of growth regulators, nutrients, vitamins and minerals. Hence, it develops diseases resistance in plants. Nutrient (micro and macro) content of this is higher than traditional composts and it can also be used as valuable soil amendment.
2. Free flowing, easy to apply, easy handling and storage and it does not produce bad odour as like residue mixed with litter in cattle shed
3. Rich in all essential plant nutrients
4. Improves soil physical properties.
5. Improves biological properties &activities in soil that help in N fixation and P solubilisation.
6. Worm gutt has some enzymes which attached to the crop residue during passing through it. The notable enzymes are protease, amylase, lipases, chitinases, and cellulose which are helpful in degradation of crop residue by microbial integration and speed up the decomposition process.
7. Composting increases the root nodulation in leguminous plants and creates symbiotic relations with mychorhiza and plant roots. And reduces phytotoxic effect ultimately increasing the yield.
8. Increases the population and activity of earthworm in the soil.
9. Eliminate weed seeds and Pathogens, enhances the decomposition of organic matter in soil
10. Improves stress tolerance in plants.
11. It can be used as rooting medium in nurseries for raising saplings.

Improve immune system of plant, keep the plants lush green colour, lustre and keeps good quality product.

CONCLUSION

Crop residue burning is major constraint in residue management, it will have effect on nutrient status in soil and plants, pollutes environment, health hazards and also increases soil temperature which will effect on soil beneficial microbial populations. Rice-wheat cropping system dominates in residue generation as compared to other cropping systems in India. Residue removal and transporting to other place for different purposes and residue incorporation needs heavy and costly machineries and is not economical to small and marginal farmers. Hence, the residue can be collected and utilised in farm by producing Vermicompost. It is cost effective, little skill requiring, easily manageable for agricultural, domestic and biodegradable wastes. It supplies high nutrient content mainly NPK, micronutrients and growth promoters, minerals etc. Compared to other compost (FYM, bacterial compost, kitchen compost), it can be applied directly on standing crop. After application of the compost, it readily and quickly releases essential nutrients to the plants. Vermiwash is also a product produced at the time of Vermicompost preparation. This can be used as a foliar spray on crops which supplies growth promoters, reduces insect pest infestation.

Continuous use of chemical fertilizers and some other factors influences low crop production, low soil fertility, depletion of sub-soil water table, incidence of pest and diseases, micronutrient deficiency have distracted Indian agricultural economy, ecological balance and food security. Vermicomposting may play a key role in organic waste management and sustains agriculture.

Table 3: Earthworm spp. used in Vermicompost their ecological niche, characters and beneficial traits (Makkar *et al*., 2017; Gupta *et al*., 2019 and Kaur, 2020).

Spices	Ecological category	Ecological niche	Characteristic features	Beneficial trait
Essenia foetida, Edrilus eugeniae, Lubricus castenuous, L rubellus, E. tetraedra, B. eiseni. B. minusculus, D. rubidus B. eiseni, and *D. octaedra*	Surface feeder (Epigeics)	Present in surfaces soil layer, leaf titter, organic matter	Uniformly pigmented and smaller in body size effective gizzards, high reproduction capacity and tolerant to wide range of climate.	Efficiently bio-degradation of OM and releases nutrients, efficient compost developer makes early decomposition.
Aporrectodea caliginosa	Endogenus	Surface soil	Worms are weakly pigmented, small to large body weight, medium duration and moderately tolerant to climatic variations.	Effective soil physical properties changes improves soil structure helps in fertility restoration.
O. cyanium and O. lacteum	Endogeic and poly-humic	Surface soil	These are rich soil feeder, horizontal borrowers and are unpigmented small In body weight.	
P. corthurus and *Allolobophora chlorotica*	Endogeic and meso-humic	Present in Soil A and B horizons	Unpigmented small in body weight and are A horizon soil feeder	
Aminthas spp.	Endogeic and oligo-humic	Present in soil B and C horizon	Unpigmented large sized worms which are extensively horizontal feeder and poor in deep soil feeder.	
L. polyphemus and *A. longa.*	Anecics	Deep burrower in soil	Dorsally pigmented large in size, extensively deep feeder and sensitive to soil disturbance and are nocturnal habitat.	Worms are vertical feeder so helping easy movement of nutrient along with water and well distributed in all horizons and better aeration will occur.

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