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RESEARCH ARTICLE

A STUDY ON ARTHROPODS AND OTHER FAUNA ASSOCIATED WITH VERMICOMPOSTING

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ABSTRACT

The present study was conducted on 10 vermicomposting units of the Gurdaspur and Amritsar districts of Punjab. *Eisenia foetida* dominated all vermi-composters mainly with cattle dung. This epigeic species is capable of better growth, multiplication, cocoon formation, and vermicomposting waste material efficiently and can withstand cold and heat environment conditions. Bacteria and multicellular organisms populate vermicomposting. Vermibin fungi include *Aspergillus, Corynascus, Penicillium, Thermomyces,* and *Trichoderma w*here *Aspergillus* dominates all fungi. All ten vermicomposting units had *Meloidogyne* nematodes. Decomposer dung bugs were numerous in cattle-dung vermibeds. Fungal gnats eat vermibed waste, Dipteran larvae eat rotting produce and debris and Summer's grey slug moved centipedes. The predatory nature of red mites and decomposing nature of white and brown mites were also observed during the investigation. Spider webs near vermicomposting operations may indirectly contribute whereas Pseudoscorpions and pot worms aid composting. Fruit flies, which eat earthworms, were more abundant in vegetable and fruit waste vermibeds. Earthworms and primary decomposer springtails accelerate decomposition. Red ants harm vermicomposting by eating earthworms. Termites harmed earthworms by delving into decomposing waste. Vermibeds' upper millipedes digest waste without harming earthworms. Vermicomposting beds only have centipedes in summer. Sparrows, crows, birds, snakes, lizards, and toads frequently visited vermicomposting beds.

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INTRODUCTION

Earthworms have been known to humans for many centuries as soil-dwelling creatures that inhabited almost every part of the planet earth and are known as "the Intestines of the Earth". The concept of vermicomposting started with the knowledge that certain species of earthworms (epigeic) grow and consume organic waste rapidly compared to other anecic and androgenic earthworms (Aranda *et al*., 1999). Compared to microbial composting, vermicomposting is faster as worms and microbes are used to digest waste material (Edwards, 1988). Aranda *et al*., (1999) offered a definition of vermicomposting, the combination of biological processes, designs, and techniques used to systematically and intensively culture huge quantities of certain species of (litter - dwelling - epigeic) earthworms to accelerate the stabilisation of organic wastes. The organic waste materials are eaten, ground, and digested by the earthworms with the aid of aerobic and some anaerobic microflora, and are then naturally converted into much finer, humified, microbe active castings where essential plant nutrients are retained.

Vermicomposting is an important component of organic farming without much financial involvement (Chandeg *et al*., 2001) and is fast and efficient to recyclecow dung,agricultural waste and kitchen waste etc. into a nutrient-rich compost which is rich in macronutrients, hormones, enzymes and beneficial bacteria (Edward, 1998). The use of vermicompost minimized the need for chemical fertilizers, increases soil fertility, enhance the water-holding capacity of the soil and reduces toxicity and leaching problems. Some earthworm species are native to temperate climates, such as *Eisenia, foetida, Dendrobaena veneta and Lumbicus rubellus*, while some come from the tropics such as *Eudrilus engeniae* and *Perionyx excavatus*. The most widely used worm *E. foetida* is reportedly tough, can withstand wide temperature conditions and become dominant in any group, at different moisture conditions and ammonia levels (Tinn *et al*., 1995). At all temperature levels, this worm shows optimum growth (weight) at moisture close to 35%.Generally, tiger worms (*E. foetida)* are preferred in vermicomposting (Dowdle and Dowdle 2002; Van zoest 2002; Rao 2005) because of the following reasons:

They can withstand temperatures from freezing up to more than 30°C. They are fast breeders, eggs hatch in a couple of days. They have a good production of cocoons and good hatching rates They mature earlier, in one week. They double their biomass in 2-3 months. They eat 50-100% of their body weight of waste per day. They can maintain more than 2000 adults per kg live worm mass. Mitchell (1997) studied the production of vermicompost from cattle dung at feedlots. The intensive activity of earthworms resulted in a significant reduction in the total mass of feed-lot cattle manure. The production of pH shift towards neutral, a decrease in conductance, huge increases in oxidation state, and considerable reductions in water-soluble chemical species that comprise potential environmental pollutants are the results of these reactions.

Fungi: The resident microbiological community has a significant impact throughout the biodegradation and conversions processes that occur during composting. Mushrooms utilise numerous carbon sources, mostly lingo-cellulosic polymer, and are able to thrive in harsh environments. They are primarily accountable for compost maturity (Miller 1996). The succession of fungi, particularly thermo-tolerant and thermophilic fungi, in typical two-phase thermogenic composting is well established (Stratoma *et al*., 1994; Ross and Harris 1983), with a mixture consisting of mushroom waste and cow manure. Once yeast was introduced, the average growth rate of earthworms raised on a mixture of 20% cattle manure and 80% mushrooms waste was determined to be 1.75 mg/ per each worm (dry biomass). Also, when yeast was added to the compost mixture, earthworms generated 2-8 times as many cocoons and 2-3.5 times as many juveniles. Antonella *et al*. (2005) examined the microbial populations in composting and organic manure. They identified and isolated 194 species of fungus, including 118 from compost and 142 from vermicompost. 66 species were shared between the two groups. In composting material, the genera *Aspergillus, Cladosporium, Penicillium,* and *Thermomyces* are considered to be the most prevalent. This may be attributable to their thermo-tolerance and ability to breakdown a wide variety of organic waste. Also reported was the relationship between fungi and arthropods, particularly insects.

Bacteria: Bacteria are the most abundant microorganisms in the compost system and the planet's major decomposers of organic materials. Enzymes secreted by these microorganisms help them digest organic matter (www.althingsorgnic.com) The types of microorganisms involved vary on environmental circumstances, that according Lind *et al*. (2002). Mostly, they are fungus, actinomycetes, and bacteria. **Nematodes**: Aira *et al*. (2003) herbivore, omnivore, and bacterivore nematode species were substantially lower in *Allalobophora, caliginosa* casts than in the surrounding soil, and there were no statistically significant changes between the micro faunal composition of casts and surrounding soil of *A. molleri*. Yeates (1981) discovered that earthworms and plant parasitic nematodes lowered overall free-living soil nematode populations by up to 66% and 66%, respectively.

Arthropods: One major difference between microbial composting and vermicomposting is the presence of insects. The higher temperature in microbial composting keeps insects away.

In vermicomposting, other than the introduced worms a good number of other organisms such as pot worms (entachyadids) and many species of Insects also take part in the decomposition of organic matter. The presence of the white worms might indicate acidic conditions that would need pH adjustment. Pot worms and several insects such as dung beetles, mites, spiders, slater bugs, centipedes, millipedes and ants naturally join the process and do not need tobe introduced into the matrix (Domingurz *et al*., 1997; Riggle,1998; Ingham, 2000; Dowdle and Dowdle, 2002; Van Zoest,2002; Roll 2002).Collembola probably affect nutrient cycling in different ways among litter and mineral layers by controlling the composition of the decomposer communities and thus the decomposition rates (Kandea and Kaneka, 2008). Collembola likely influence nutrient cycling in distinct ways between litter and minerals layers by regulating the composition of decomposer populations and, consequently, soil microbial activity (Kandea and Kaneka, 2008). Collembola are reported to consume bacteria, fungi, mineral soil particles, organic materials, protozoa, and nematodes. Collembolans feed directly on nematode (Gilmore 1970; Lee and Widden, 1996), whereas they may enhance nematode growth via boosting microbial activity and biomass. Consequently, they may indirectly affect the microporous nematode biomass. When collembolan was present, the number of nematodes decreased by nearly 90% in 24 hours. Collembola is believed to consume a wide variety of items, including fungi, algae, trash, and even other soil animals (Recess *et al*., 2005). So according Chahartaghi *et al*. (2005), the huge collembolans identified in the pig slurry composting bins might be classified as secondary decomposers that feed primarily on fungi. This is consistent with prior discoveries of large collembolans that often inhabit vermicomposting beds (Monroy, 2006).Staphilinidae beetles are classified as facultative predators, and their occurrence at a significant tropic level among soil macrofauna has been documented (Schen and Falca, 2000). Yet, there are also non-predatory groupings, such as saprophagous and even fungal-feeding organisms, thriving in other areas (Ashe, 1984).

Arthropods as Decomposers: Seastedt (1984) observed the role of micro and macro arthropods in decomposition. According to him, Collembolans are the major group of arthropods which cause the decomposition of different types of wastes. These insects arefound in all decomposing places. The presence of collembolans, the springtails in the vermibins and their possible role in decomposition were alsodiscussed by Martin *et al*. (1999). According to them, springtails constitute 80% of collembolans. They cause decomposition in the bin and do not cause any harm to earthworms. They also mentioned the role of sow bugs and millipedes in the process of vermicomposting, both of them were decomposers and beneficial to the vermibins. Three combinations of residue (w/w) viz.*Areca l*eaf litter and nut husk (1:1), Cocoa leaf litter and Cocoapod husk (1:1) and mixed leaf litter (*Areca, Cocoa, Cashew and Acacia* (1:1:1:1) in cement tanks were offered to millipedes with adequate moisture up to two months for composing. As a result organic material and C/N ratio subsequently declined in treated than control residue. At the same time, pH was shifted from acidic to neutral and the formation of good-quality compost was reported. Dangerfield (1993) was the first to report the ingestion and assimilation of leaf waste in some tropical millipedes. This was the first report on the direct role of arthropods in composting. Lawrence and Sainways (2003) observed the role of litter breakdown by the *Seychelles* giant millipede. According to them, the giant millipede eats on the litter available and causes fragmentation and mineralization of mineral nutrition.

Arthropods as Pests on Earthworms in the Vermicomposting: Different invertebrates such as flatworms, carnivores slugs, carabids and staphylinid beetles and their larvae, centipedes and Acari (Chigers) have been reported as pests of earthworms(Edward and Lofty, 1977; Gruff, 1987; Kale 1998).Reddy *et al*. (2003) found *Lobella sp* (Collembola), aserious pest of *Eisenia foetida* in the vermicomposting unit at Warangal in Andhra Pradesh. *Lobella sp*. was found as a serious pest which attacks the anterior and posterior ends of earthworms and causes the worm to wriggle vigorously, but when they attack the middle portion, they disintegrate the body in two parts with their sharp claws. Their sucking mouth parts may be used for the body fluid of earthworms. The attack was observed only onthe upper five-centimetre layer of vermiwaste. During this study, they also observed two species of ants *viz. Monomorium sp*. and *Poaratrechina sp*. attack and kill earthworms in the plastic bins containing vermicompost of kitchen waste. Martin *et al*. (1999) also mentioned the presence of several species of ants that mainly feed on high-concentrate feed in worm beds, but some species are reported to feed on eggs and small worms in the bin. Mulri *et al*. (2006) found that during vermicomposting of coconut leaves by different species of earthworms, viz., *Eudrilus sp., Oryctes rhinoceros* an insect pest of palm breed in the decomposing material. The presence of fruit fly larvae, centipedes and millipedesas the main competitors of earthworms for food was observedby Martin *et al*. (1999).The occurrence of insects in vermicomposting units is dependent on locality and climatic conditions (Davies 1988).Common housefly populations increase very rapidly in waste as the young maggots can emerge from eggs within a timeframe of 8hours. In a properly kept vermicomposting bin, flies and cockroaches would not be found because of the nature of waste conversion, but snails could be found at times. All these insects, like the worms, take part in the decomposition of the waste materials and mineralisation process (Kostecka. 2001). Earthworms are subjected to predation by terrestrial vertebrates (birds, amphibians, shrews and reptiles) as well as other parasites found within the decomposing matrix. Small red mites found in the vermicomposting bins sometimes attack the composting worms by consuming the live worm's body parts, after which the worm appears to have withered body segments (Slocum, 2006). While predation from insects taking part in the process, such as red mites, cannot be avoided entirely (Hacdonald 1983; Ingham *et al*., 1985; Dowdle and Dowdle2002).

MATERIALS AND METHODS

Selection of Vermicomposting Sites: 10 vermicomposting units were selected for the study. The selection was based on the parameters like type of waste used and the location of vermibeds (indoor or outdoor).Out of 10 vermicomposting units studied, 6 were from the district of Gurdaspur and from the Amritsar district of Punjab. In the Gurdaspur district, 4 vermicomposting units were outdoor and two indoor. In outdoor vermibeds 3 were using cattle dung wastes. In one vermicomposting unit pig waste and in the second one industrial waste was used. Out of the two indoor bins one was using vegetable waste and the second one was using cattle dung and domestic waste. Out of the 4 vermicomposting units studied in the Amritsar district of Punjab, two were indoor and two outdoor. The indoor vermicomposting unit is using cattle dung, domestic waste and vegetable waste. The outdoor unit was using cattle dung and pig waste.

Species of Earthworms Used by the Farmers: The different species of earthworms used by the farmers were collected and identified.

Mode of Vermicomposting: Following modes of vermicomposting were encountered during the study.

- Vermicomposting in pit
- Vermicomposting in concrete tanks
- Vermicomposting in well rings
- Vermicomposting in wooden crates/bins
- Vermicomposting plastic crates/bins
- Vermicomposting on elevated ground
- Vermicomposting in metal containers

Outdoor and Indoor Vermicomposting: Out of the given sample size, how many are performing vermicomposting in outdoor and indoor sites. The outdoor location of beds was requiring constant attention. Attack of pests and predatory animal species are some of the problems faced by these farmers.

Type of Material Used for Vermicomposting: This part of the study includes data collection regarding the type of material used for vermicomposting. Out of the following, which type of material is used in the vermicomposting units for vermicomposting purposes: Animal dung, consolidated organic matter, droppings of poultry, animal waste (vegetable waste, fruits), Kitchen waste from households and restaurants, Forest wastes (forest leaf litter, grasses, wood shavings, weeds, sawdust, peals and pulps etc.Industrial wastes (different types of agro-industrial wastes from food processing, distillery, sericulture, sugar industry, coir industry, seed processing units and oil extracting units).Market wastes, Newspapers, other paper waste and cotton cloths, Eggshells, Fats, oily foods, meat, excreta of meat eaters (such as dogs and cats),Fruits such as citrus, garlic, onions and heavily spiced food wastes.

Fungi Culture and Identification: Fungi were cultural and examined according to Trombetta *et al*. (1998)To disperse organic colloids, a 10g quantity of each sample was soaked in 90 ml $Na_4P_2O_7.10H_2O$, and subsequent dilutions were produced in NaCl (0.9%). The final dilution (1:20,000) was mounted (1ml per plate) on 5 replicates of laboratory-prepared potato dextrose agar (PDA) medium.

To prepare PDA Medium

Reagents Required

Potato Infusion – 200gms
Dextrose 20gms
Agar – 20gms
Distilled Water –1-litre
Potato infusion was prepared by boiling 200 gms of sliced, unpeeled potatoes in 900 ml. of distilled water for 30

minutes. Potatoes were washed and filtered through cheese cloth. The effluent was used as potato infusion. Then dextrose was dissolved in 100 ml water. This was mixed with potato infusion. Now agar was dissolved in this mixture and boiled. This mixture was autoclaved for 16 minutes at 121°C and dispensed 20-25 ml portions into pre-sterile 15x100 mm Petri dishes.

The final pH of the PDA was between 3.5-4.Inoculation was done by pour-plate method and the plates were incubated at 25-28°C for 3-5 days. The number of colony-forming units per gram of dry weight (CFU/gdwt) was calculated. Fungi were identified with the help of experts from the microbiology Department of Guru Nanak Dev University, Amritsar.

Extraction of Soil Fauna

Nematodes: Nematodes were extracted from 10g vermicompost inmodified Bearmann funnels. The earthworm samples were covered in cheesecloth and set in a funnel filled with water. Nematodes could only swim downward in huge volumes of water due to their muscular anatomy, therefore they amass over time towards the bottom of the funnel. Seven days later, the funnel was unsealed and a few millilitres of water were gathered. The solution was observed using a microscope. Individual nematodes were collected and mounted on slides for identification purpose. The identification was done withthe help of taxonomic keys.

Arthropods: The large arthropods belonging to orders like Coleoptera, Diplopoda, and Chilopoda are picked up with the help of forceps or directly by hand. They are killed by dipping in alcohol. Photographs were taken for the purpose of record and identification. The number of arthropods per square foot of vermicomposting was calculated.

Collembolan and enchytraeids were obtained by accelerated wet extraction by gently dispersing sub-samples of vermicompost (200g f.w.) with 600 ml cold distilled water for 5 minutes in glass beaker. Collembola was separated by floatation. These were immediately collected from the water surface on a piece of aluminium foil and gently removed with a paintbrush.

These were washed again with distilled water and followed concentrated by decantation. Other micro arthropods were collected by Tullgren funnel. This method was extracted by using Berlese –which uses both moisture and temperature gradients. A weigh boat was placed onto the scale and tared. Weighed out 100 grams of moist unfinished vermicompost. Gently placed the sample onto the mesh screen inside the Berbse funnel assembly. Poured about 50ml of ethanol into the beaker at the base of the assembly and reassembled. The unit was notdisturbed. 60 W light was turned on above the unit and incubatedfor 1 day. After 1 day the insects were collected, examined and counted. The density of collected microarthropods was represented by the number of organisms per unit of vermicompost dry weight (gram dry weight).

Other Vertebrates: Regular observations and enquiries from the vermin farmers were done to know about different kinds of animals occasionally visiting the bins for eating earthworms and other organisms.

RESULTS AND DISCUSSION

The species of earthworms used in all the selected vermiculture farms were identified as *Eisinia foetida*. According to the farmers, it is the most successful and well-adapted species of earthworm in all seasons. Tripathi and Bhardwaj (2004) have also shown that *E. foetida* is a better-adapted species under the tropical conditions of Rajasthan. It shows better growth, multiplication and cocoon formation. It is found to be the best species for vermicomposting the organic waste material in the area of north India. Castillo *et al*. (2005); Loh *et al*. (2005); Kaviraj and Sharma (2003) also agreed that the most successful species of earthworm used in vermicomposting is *Eisinia foetida.* Out of ten vermicomposting units, six were outdoor and four indoor. They were also classified according to waste used in vermicomposting. Six were using exclusively cattle waste, two were using pig waste, one was using vegetable and kitchen waste and one was using sugar mill waste as given in Table No. 2. Cattle dung is the most preferred waste in all the vermin units which is used in vermicomposting in different compositions with other wastes. Loh *et al*. (2005) also agreed that cattle manure provided a more nutritious and friendly environment. While Kaushik and Garg (2004) found that the maximum growth and reproduction of *Eisenia foetida* was observed in 100% cow dung. The worms grew and reproduce favourably in 80% cow dung mixed with solid textile mill sludge. So, the best waste material to be used in vermicomposting is cattle dung.

Mites: Some species of mites were reported in large numbers in nearly all the vermibins studied. They were the visible decomposers which feed on dead organic matter, fly larvae, other small organisms and even on earthworms. It is found that in the highly infested bins, earthworms do not come in the uppermost layer of vermicompost, which shows that mites act as predators of earthworms. Mainly three types of mites were observed in most of the bins. These are white mites, and brown and red mites. White and brown mites were found on the upper surface of compost which showed no interaction with earthworms and their possible role in the decomposition of waste, while red mites were found close to earthworms which shows their predatory nature. Seasonal variations in the number of mites showed that their number increased at a high rate during summer (April -September), especially in the humid months. They have four pairs of legs, large rounded bodies and small heads, their colour change from mottled brown to white and red. The presence of different species of mites including red mites was also reported by Martin *et al*. (1999). Some articles in previous literature also mentioned the presence of mites in the bins. According to these reports, mites are mostly decomposers but some species may be predators of other organisms including earthworms (www.google.com, www.allthingsorganic.com). But none has discussed the seasonal variations. Lyon (1996) described that red mites are predators of earthworms and they suck the body fluid of earthworms.

Spiders: Spider webs were observed in and near the vermibeds. They have no role in vermicomposting but this may be due to the presence of a large number of dipterans which are the food for spiders. Although not directly but they are beneficial as they trap unwanted visitors in the bins and provide natural control of pests of earthworms.

Table 1. Detail of vermicomposting units chosen for the study

S.No	Name of Site where vermicomposting unit is located	Number of Vermibeds	Indoor/ Outdoor	Measurement (Per. Square Feet)
1.	G.N.D University Campus, Amritsar	10	Indoor	8×3
2.	G.N.D University Campus, Amritsar	10	Outdoor	5×2
3.	Verka, Amritsar	5	Outdoor	10×3
4.	Jalandhar Raod Amritsar	10	Indoor	10×3
5.	Khanowal I(Gurdaspur)	8	Indoor	10×3
6.	Khanowal II(Gurdaspur)	10	Outdoor	10×3
7.	Pania Sugar Mill(Gurdaspur)	18	Outdoor	5×3
8.	Dhar Kalan(Gurdaspur)	7	Indoor	15×3
9.	Jaintipur (Gurdaspur)	20	Outdoor	20×3
10.	Johal Nangal(Gurdaspur)	9	Outdoor	20×3

Table 2 Different Invertebrate species associated with vermicomposting units

S.No	Name of Site where vermicomposting unit is located	Number of Vermibeds	Indoor/ Outdoor	Measurement (Per. Square Feet)	Waste Material used
1.	G.N.D University Campus, Amritsar	10	Indoor	8×3	Cattle dung
2.	G.N.D University Campus, Amritsar	10	Outdoor	5×2	Pig waste
3.	Verka, Amritsar	5	Outdoor	10×3	Cattle dung
4.	Jalandhar Raod Amritsar	10	Indoor	10×3	Cattle dung
5.	Khanowal I (Gurdaspur)	8	Indoor	10×3	Cattle dung
6.	Khanowal II (Gurdaspur)	10	Outdoor	10×3	Sugar mill waste
7.	Pania Sugar Mill(Gurdaspur)	18	Outdoor	5×3	Pig waste
8.	Dhar Kalan (Gurdaspur)	7	Indoor	15×3	Cattle dung
9.	Jaintipur (Gurdaspur)	20	Outdoor	20×3	Cattle dung
10.	Johal Nangal(Gurdaspur)	9	Outdoor	20×3	Cattle dung

Table 3 Different invertebrate species associated with vermicomposting

Soil invertebrates commonly found in vermicomposting		Soil Invertebrates that can be predator or pest in vermicompost	
Earthworms	Oligochaetes	Roundworms	Nematoda
Millepedes	Diplopoda	Centipedes	Chilopoda
Wood lice	Isoda	Mites (Red)	Acarina
Mites	Acarina	Pseudoscorpions	Pseudoscorpionida
Springtails	Collembolan	Beetles	Coleoptera
Beetles	Coleoptera	Termites	Isoptera
Fly larvae	Diptera	Flies	Diptera
		Earwigs	Dermaptera

No seasonal variations in the number of spider webs were observed but they were more in undisturbed vermiculture units.

Pseudoscorpions: Pseudoscorpions were found in clusters just below the 5-6 inches of upper layers of compost. They do not show any interaction with earthworms and appeared as decomposers or possible predator parasites of organisms. They are more in number in cattle dung as compared to other waste materials used in the selected vermibins. They are false, tiny false scorpions with no stings. The seasonal variations showed that their number is high in the hot and humid months of July-August and low in winter i.e. November-February.

Fruit Flies: *Drosophila* spp. and their larvae were found in large numbers in all the vermibins studied but their number was comparatively low in vermibins using a high percentage of cattle dung. Their number was high in vermibeds using vegetable and fruit waste, where they compete with earthworms for food. Otherwise, their presence does not affect the earthworms. In the summer season, their number was five times higher than in winter. They were more in outdoor bins, so need to employ strict control measures.

Fungal Gnats: The small black-coloured dipterans, the fungal gnats were found to eat fungus grown in the bins. Their larvae were also found to act as decomposers and feed on dead decaying matter. The larvae of fungal gnats were the food of other organisms in the bins like beetles and nematodes. No increase in their population was observed during the summer months.

House Flies: Houseflies were observed as common visitors of the vermis. They were found sitting on bins when there is enough unfinished food available. They were more in pig waste, vegetable and kitchen waste, where more protein and carbohydrates were available. In vermibins, housefly larvae were found in large numbers. In cattle dung waste no housefly larvae were seen. The houseflies were found only during the summer months i.e. March to October. Seastedt (1984) discussed the role of dipteran larvae as a voracious feeder of fruit, vegetable and other waste in the process of composting. Some information on the internet was also available which mentioned their presence in the vermibeds (www.allthingsorganic.com). But no research paper was found that gives any information regarding their role in vermicomposting.

Beetles: Dung beetles of the family geotrupidae of small and large sizes were observed in most of the bins. Their number is more where a large percentage of cattle dung is used. They are well-known decomposers which feed upon dung and help in its decomposition.

But as they are large in size, ugly creatures which create problems in handling vermicompost. They are black in colour, with two pairs of wings, forewing hard and sheath like, and hind wings large and membranous, they can fly small distances and have chewing-type mouthparts. The presence of beetles of the family staphilinidae in vermibeds was mentioned to occur as facultative predators on other organisms by Secher and Falca (2000). According to Sampedro and Dominguez (2007), these coleopterans may be predators or fungal feeders depending upon conditions. No report about the role of dung beetles was found. Gopal *et al*. (2006) also found *Eudrlus* spp. *Oryctesrhinoceros L* (Beetle) is an insect pest of palm to breed in vermicomposting.

Springtails: The most numerous and important decomposers in any composting process were the springtails. These were observed in large numbers in all the vermibins studied. They were clearly visible with a hand lens. They have six legs and a pair of antennae. They possess jumping organ fercula on the ventral side of the fourth abdominal segment with which they jump. They are the primary decomposers of all types of organic waste, so speed up the decomposition and help the earthworms in large vermicomposting. Their number was more in indoor vermicomposting as compared to outdoor vermicomposting. This may be due to fewer disturbances of indoor vermicomposting by other visitors. Their number was more in the summer season. According to Seastedt(1984) Collembolans were the major group of arthropods which cause the decomposition of all types of waste and are found in every place where decomposition is taking place. The presence of springtails in the vermicompost was also confirmed by Martin *et al*. (1999). According to him, springtails constitute 80% of collembolans which cause decomposition and do no cause harm to earthworms. No other collembolan was reported during this study while Reddy *et al*. (2003) found *Lobella sp*. (collembolan) as a serious pest on earthworm, *E. foetida* at Warangal (Andhra Pradesh).

Ants: Many species of ants of the family Formicidae were observed as regular visitors of vermibeds while some burrow deep and form colonies. They are attracted by protein and carbohydrate-rich food in the bins. Red ants, *Solenopsis* were found predating on small and weak earthworms and larvae of other invertebrates present in the bin. So, these are harmful and should be kept out of the bin. Martin *et al*. (1999) also mentioned the presence of several species of ants in vermicomposting. According to him, ants feeds mainly on high concentrate feed in worm bins, but some species are reported to feed on eggs and small worms.

Termites: The always harmful insects, the termites are also observed in some vermicomposting units. They reach deep into the vermibeds and cause harm to vermibeds. These insects were observed only in area where termite colonies were present and proper control measures were applied.

Earwigs: Dermaptera were not many earwigs were observed in the only site in district Gurdaspur both in indoor as well as outdoor vermibins. They stay deep in the vermibins, and get quickly inside the bin when removed. They were fast-moving, large (1 - 2 inches) in size with one pincer-like appendage at the tip of the abdomen. They may be the possible predator of earthworms.

Sow bugs: The sow bugs also known as woodlice or roly-poly bugs were also reported in the vermibeds. They feed mainly on tough woody material. They have a dorso-ventrally flattened body, light brown to dark grey in colour with an armoured segmented body shell, pairs of legs and a pair of antennae. They are omnivorous and found in all areas of the bins. According to Martin *et al*. (1999), the sow bugs are decomposers which eat tough woody material rich in cellulose, and lignin and are resistant to microbial attack. So, the presence of sow bugs is a good sign for vermicomposting.

Millipedes: These are similar to centipedes but with two pairs of legs in each segment. The millipedes were also reported in most of the outdoor bins. The species observed were brown to reddish brown, having armoured shells for protection and these coil into a ball when touched and were found mainly on the upper 4 - 5 inches of vermicompost, causing decomposition of waste without causing harm to earthworms. They were observed only in the summer season. The decomposition by pill millipedes *Arthrosphaera magna* was studied by Ashwini and Sridhar (2006) on a pilot scale. After two months the leaf litter was converted into a good quantity of compost. Dangerfield (1993) also reported the role of the Southern African millipede, *Alloporus uncinalus* in the decomposition of leaf litter in mineral soil which is converted to nutrient-rich compost. Lawrence and Sarnways (2003) also reported that giant millipede eats upon the litter available so causing fragmentation and mineralization of nutrients. So, their presence in the bin is a good sign for vermicomposting.

Centipedes: Some centipedes are not very common, but are found in some vermibeds in small numbers. Centipedes are normally carnivorous and eat other organisms, so may be harmful in vermicomposting. They can be easily removed by forceps. They are dark brown to reddish in colour with a flattened, cylindrical body and have one pair of legs in each segment. They have a pair of huge formidable pincers that curve behind the head with which they subdue prey larger than themselves. They are seen only during the summer season.

Potworms: The small white segmented worms, the pot worms are found in large numbers in all the vermicomposting units studied. They are beneficial organisms in the bins just like earthworms and help in the decomposition of waste. They are found in deep areas along with earthworms and look like baby earthworms. They are beneficial for vermicomposting. They are found in all seasons but the number was significantly greater in summer. The presence of pot worms in vermicomposting bins was also reported by Martin *et al*. (1999). He also agreed about their beneficial role in vermicomposting.

Mollusks: The slug, *Limax*, commonly known as 'grey slug' is found in small numbers during the months of May - June in two outdoor vermibeds which were undisturbed for a long time. They were found escaping on the vermibeds with the help of their muscular foot. No interaction with earthworms was seen.

Nematode: A large number of nematodes of *Meloidogyne* spp. were extracted from all the vermicomposting units. Their number was found greater in fresh waste as compared to finished vermicompost, which shows that earthworms decrease their numbers in the vermicompost.

Dominguez *et al*. (2003) found that the number of nematodes in cattle dung containing earthworms decreased as compared to the increase in cattle dung without earthworms. Dash *et al*. (1980) are of the view that earthworms can ingest and digest nematodes while according to Yeates (1981), nematode population decreases due to indirect effects like modification in soil structure, waste regime and nutrient cycling process. Dominguez *et al*. (2003) reported two types of nematodes in vermicomposting, these were bacterivore and fungivore.

Fungi: The fungi which are primary decomposers in all the decomposition processes were also studied during a present investigation.
The main groups of fungi identified were

- *Aspergillus* spp: More than five species of the *Aspergillus* genus were isolated. They constitute the major group in all the fungal populations studied.
- *Corynascussp*: The second major group of fungi found was *Corynascussp*
- *Penicillium* spp.
- *Thermomyces*
- *Trichoderma*

In addition to these genera, many other fungi were also present but to identify those in proper was the shortcoming of this study. The active component involved in the biodegradation and conversion process during composting is the resident microbial community, among which fungi play a very important role. According to Sparkling *et al*. (1982) the biomass ratio of fungi to prokaryotes in compost is about 2:1. It was reported by Manuel *et al*. (2006) that *E. foetida* enhances fungal communities in vermibeds to trigger more efficient cellulose decomposition. Edward (2004) assumed that microorganisms especially fungi were part of earthworm diet. Periera *et al*. (1999) have studied the survival and saprophytic ability of *Trichoderma harzianum* in sugarcane industry waste. Antonella *et al*. (2005) isolated and identified 194 species of fungi in compost and vermicompost, out of which 142 comes from vermicompost. Only 66 were common to both. According to them, *Acremonium, Aspergillus, Cladosporium, Penicillium, Malbranchea* and *Thermomyces* genera were regarded as most common in vermicomposting which recognized the results in this research work.

Other Vertebrates: Vermibins were not the home of larger vertebrates, but they were observed to visit the bin occasionally to get food out of it. Birds: Many birds like sparrows, crows, and dove, were observed as regular visitors in outdoor vermibins.

Reptiles: Snakes also visit the vermibins for their food. Two farmers from different sits seen snakes around their vermibeds. Lizards also visit to eat small insects. Amphibians: Toads grouping around the vermibeds were observed in the rainy season. They are sometimes buried inside the wet vermicompost to eat earthworms.

In all the vermicomposting units studied the main earthworm species was *Eisenia foetida.* The arthropods constitute the largest group of animals found to be associated with earthworms in composting sites. The number of arthropod species shows a great variation in different vermi units of different localities. Mites, spiders, pseudoscorpions, fruit flies, fungal gnats, house flies, beetles, springtails, termites, earwigs, sow bugs, millipedes, centipedes and pot worms are the different arthropod species encountered during the present research work. The mites showed seasonal variations in their population. Their number increased in all the vermibins during the summer season, especially in the humid months. The spiders and their webs found near vermicomposting sites seem to play an indirect role. Similarly, pseudoscorpions do not show any interactions with earthworms and they simply act as physical decomposers. Their population is high during hot and humid months and low in the winter season. The population of fruit flies was found to be higher in vermibeds using vegetable and fruit waste.
They act as a competitor for food with earthworms. Their population show a decline in vermibins using a higher proportion of cattle dung. The adults and larvae of fungal gnats are also found as decomposers in the decaying waste of vermibeds. The dipteran larvae are found to act as a voracious feeder of fruits, vegetables and other wastes in process of composting. The dung beetles, acting as decomposers, were observed in large numbers in those vermibeds where a high proportion of cattle dung is used. Springtails acting as primary decomposers speed up the decomposing process along with earthworms. Red ants were found as predators of weak and small-sized earthworms, thereby acting as harmful creatures during vermicomposting. Similarly, termites were also found to harm the vermis by reaching deep into the decaying matter. Millipedes found in the uppermost layers of vermibeds cause the decomposition of waste without causing any harm to earthworms. The movement of centipedes was observed in vermicomposting beds during the summer season only. The pot worms prove beneficial to increase the rate of composting. Many birds like sparrows, crows, dove and reptiles like snakes and lizards and amphibians like toads were also found to visit the vermicomposting beds. Red ants were found as predators of weak and small-sized earthworms, thereby acting as harmful creatures during vermicomposting

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