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Earthworm Diversity and Abundance in Various Cropping Systems under Conventional and Organic Farming

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Abstract

Earthworms form an integral part of the soil ecosystem, contributing to the development of soil structure, nutrient cycling, pedogenesis, water regulation and pollution remediation. The present study is an attempt to assess the earthworm abundance and diversity in the different cropping systems (basmati-wheat, basmati-chickpea, soybean-wheat, moong-wheat) under organic and conventional farming systems in the fields of Punjab Agricultural University, Ludhiana. The four earthworm species found during the study period are Metaphire posthuma, Lampito mauritti, Amynthas morrisi and Travoscolides chengannur which belong to two families - Megascolicidae and Octochateidae. Out of these Travoscolides chengannur was reported for the first time in Punjab. The results indicated that richer earthworm diversity is found in the organic farming systems as compared to the conventional farming systems. The annual overall abundance of earthworms in kharif season i.e. M. posthuma (61.75) was found in basmati rice-wheat, (62.75) in basmati rice-chickpea, (36.5) in soyabean-wheat, (43.5) in moong-wheat cropping systems in the organic farming. This abundance was higher as compared to the conventional farming as found (8.2) in basmati rice-wheat, (9.2) both in basmati rice-chickpea and soyabean-wheat, (8.2) in moong-wheat cropping systems (Rabi). The same trend was found for other species. The current study demonstrates that conventional farming management practices such as chemical fertilizers and pesticides negatively influence the earthworm population, which could explain the existence of fewer earthworm species in conventional fields.

Keywords: Earthworms; Abundance; Diversity, Organic farming; Conventional farming; *Travoscolides chengannur*

Introduction

Earthworms belong to Phylum Annelida, Class Oligochaeta and Family Lumbricidae. Inside the phylum Annelida, three important categories have been traditionally acknowledged. These include Polychaeta, Oligochaeta and Hirudinea. Talking about their phylogenetic relationship, Oligochaeta has evolved from Polychaeta (Struck et al., 2011). The various land use patterns have affected the diversity and abundance of earthworms. The attention of many researchers has been drawn to aboveground biodiversity, but scientific knowledge on soil species has remained ignored and their possible benefits have not been completely achieved (Rossi and Blanchart, 2005). Different studies have shown that changes in land use structures have impacted the structure, functionality and dynamics of soil species with a major effect on critical soil functions (Decaens, 2010). Normal and relatively undisturbed habitats foster a wide range of earthworms due to the availability of adequate niches for them.

The appropriate niches for their growth, natural and relatively undisturbed habitats promote a rich diversity of earthworms. Owing to habitat alteration and food distribution, the disturbed or fragmented soils typically have low earthworm populations (Lavelle, 1992). In most degraded soils, their activities are usually poor, mainly the ones associated with agriculture and forest (Lavelle, 1992). Recent studies have shown that land use intensification and anthropogenic intervention cause random shifts in soil communities that have a long-term effect on ecological services (Dupouey et al., 2002). Earthworm populations significantly improve the soil structure by various mechanisms like provision of adequate aeration to the soil, creating deep burrows and mixing the organic residues well with the soil particles. Earthworms also stimulate microbial species in their gut and casts, such as nitrogen-fixing bacteria, which promote soil fertility, increasing plant growth and crop yield. Hence, all these activities of earthworms engender their name as 'indicator' organisms to assess the biological effect of soil contaminants (Rochfort et al., 2009). Also, the soil management practices heavily intervene the activities of earthworms within the soil. Any modification in their activity thus indicates the fertility and quality aspects of the soil. Furthermore, some earthworms feed on toxic soil nematodes. Such species of earthworms help in reducing the population of poisonous nematodes in the soil. (Arancon et al., 2005).

Scientists show considerable interest in exploiting earthworms to break down complex organic waste into simpler forms (Alagesan and Dheeba, 2010). Via decomposing organic materials, the earthworms run the energy transformation cycles through the mineralization of organically bound nutrients such as lignocellulose (Bhadauria and Ramakrishnan, 1989). This deterioration of organic materials by earthworms is due to the presence of various degrading microorganisms in their guts (Edwards and Bohlen, 1996). Earthworms have procured increased scientific attention in India as well as other countries due to their broad utilization in the bioremediation of soil, vermicomposting and as an important source of easily digestible animal protein for livestock. Many species of earthworms are also bio-indicators for detecting chemical toxicity in the soil. This is because the earthworms tend to accumulate considerable amounts of such chemicals inside their tissues. With their unique food and feeding habits, earthworms are the most useful converters of organic waste in nature therefore, earthworms are very beneficial to humans in many aspects.

Materials and methods

Collection, preservation and population count of earthworms

The four different organic and conventional farming systems studied were basmati-wheat, basmati-chickpea, soybean-wheat, and moong-wheat at the experimental area of the School of Organic Farming, College of Agriculture, Punjab Agricultural University, Ludhiana. The fields had a plot size of 15m × 9m. These fields were surveyed at monthly intervals for one year. The sampling of earthworms was done on monthly basis using hand sorting method. In addition, the GPS data of each sampling location were recorded. (Table 1 and 2). The earthworm sampling method of Singh et al. (2016) was followed.

Table 1. The sampling sites under organic fields

S. No.	Sampling Sites	Vegetation	Latitude	Longitude
1	**ORGANIC FIELDS**	Basmati-Wheat	30°90'13"	75 ° 78'77"
2		Basmati-Chickpea	30 ° 90'48"	75 ° 78'50"
3		Soybean-Wheat	30 ° 90'93"	75 ° 78'05"
4		Moong-Wheat	30 ° 90'17"	75 ° 78'22"

Table 2. The sampling sites under conventional fields

S. No.	Sampling Sites	Vegetation	Latitude	Longitude
1	**CONVENTIONAL FIELDS**	Basmati-Wheat	30 ° 91'06"	75 ° 78'60"
2		Basmati-Chickpea	30 ° 91'32"	75 ° 78'68"
3		Soybean-Wheat	30 ° 91'44"	75 ° 78'61"
4		Moong-Wheat	30 ° 91'68"	75 ° 78'15"

Collection and Identification of Earthworms

At each study site, earthworms were hand-sorted up to 50 cm deep (25 cm x 25 cm) under organic and conventional farming systems. The earthworms were extracted from the previously described block. To gather the deep-burrowing earthworm individuals, the same region was dug deeper using a shovel. The earthworms were properly washed with tap water and left to dry on filter paper. Further, the earthworms were killed using 70% ethanol and preserved in a 5% formalin solution.

Table 3. Distribution of earthworm species and their annual abundance (%) of kharif and rabi seasons in organic and conventional field

a) Basmati-Wheat Cropping system

SPECIES	Basmati				Wheat			
	Organic		conventional		Organic		conventional	
	Mean	AA	Mean	AA	Mean	AA	Mean	AA
M. posthuma	61.75	0.531183	50.75	0.604167	8.2	0.602941	7	0.714286
L. mauritii	38.25	0.329032	27.25	0.324405	3.4	0.25	1.8	0.183673
A. morissi	14	0.12043	6	0.071429	2	0.147059	1	0.102041
T. chengannur	2.25	0.019355	0	0	0	0	0	0

Simpson's index	0.40	0.47	0.43	0.54
Shannon weiner diversity index	1.03	0.85	0.93	0.78
Species evenness	0.74	0.78	0.84	0.71

b) Basmati-chickpea cropping system

SPECIES	Basmati				Chickpea			
	Organic		conventional		Organic		conventional	
	Mean	AA	Mean	AA	Mean	AA	Mean	AA
M. posthuma	62.75	0.535181	56	0.632768	9.2	0.582278	5.4	0.675
L. mauritii	39.5	0.336887	25.75	0.29096	3.8	0.240506	2.4	0.3
A. morissi	15	0.127932	6.75	0.076271	2.8	0.177215	0.2	0.025
T. chengannur	0	0	0	0	0	0	0	0

Simpson's index	0.41	0.48	0.42	0.53
Shannon weiner diversity index	0.96	0.84	0.96	0.71
Species evenness	0.87	0.76	0.87	0.65

c) Soybean-Wheat cropping system

SPECIES	Soybean				Wheat			
	Organic		conventional		Organic		conventional	
	Mean	AA	Mean	AA	Mean	AA	Mean	AA
M. posthuma	36.5	0.640351	23.75	0.629139	9.2	0.630137	5.8	0.58
L. mauritii	12.75	0.223684	6	0.15894	8.5	0.232877	1	0.1
A. morissi	7.75	0.135965	8	0.211921	2	0.136986	3.2	0.32
T. chengannur	0	0	0	0	0	0	0	0

Simpson's index	0.47	0.46	0.46	0.43
Shannon weiner diversity index	0.89	0.91	0.90	0.91
Species evenness	0.81	0.83	0.82	0.82

d) Moong-wheat cropping system

SPECIES	Moong				Wheat			
	Organic		conventional		Organic		conventional	
	Mean	AA	Mean	AA	Mean	AA	Mean	AA
M. posthuma	43.5	0.5625	21.33	0.554113	8.2	0.577465	4.2	0.617647
L. mauritii	24.6	0.318966	11.5	0.298701	3.4	0.239437	1.4	0.205882
A. morissi	9.16	0.118534	5.67	0.147186	2.6	0.183099	1.2	0.176471
T. chengannur	0	0	0	0	0	0	0	0

Simpson's index	0.43	0.41	0.41	0.43
Shannon weiner diversity index	0.94	0.97	0.97	0.92
Species evenness	0.85	0.88	0.88	0.84

Then, using a stereomicroscope, all the preserved earthworms were examined for various characteristics such as the total number of segments, prostomium shape, position and type of clitellum, position and number of spermathecae, position of male pore, and total length (in cm) using measuring scale. Earthworm samples were examined under a microscope to determine these external traits.

Earthworm ecological indices

Relative abundance

Individual earthworms were identified at the species level and grouped into three ecological groups: Anecic, Epigeic, and Endogeic. Each earthworm species' relative abundance was determined as a percentage. To calculate the relative abundance of each earthworm species, the following formula was used

$$\text{Relative abundance}(\%) = \frac{\text{Number of earthworm individuals in each species}}{\text{Total number of Individuals}} \times 100$$

Simpson index (D)

The Simpson index measures the degree to which a species outnumbers its competitors in an ecological community. Its value ranges from 0 (no species present) to 1 (one species dominating completely). As a result, the higher the values of D, the lower the diversity, and vice versa. The Simpson Index was computed using the following formula:

$$D = \sum \left(\frac{n}{N}\right)^2$$

n = Number of earthworm individuals in each species,
N = Whole number of earthworm individuals

Shannon-Wiener Diversity Index (H′)

The "Shannon and Wiener index (1949) measures "the earthworm species diversity index. Its formula is:

$$(H') = -\sum pi \times \ln pi$$

pi = Proportion of total sample represented by a species i,
ln = logarithm to base e

Species evenness index (E)

Pielou's"evenness is related to species evenness and therefore Pielou's"evenness index is known for calculating the "species evenness index (Pielou, 1966). Its formula is

$$E = \frac{H'}{\ln S}$$

H′ = Shannon and Weiner diversity index,
S = number of species.

Table 4. Species present in different cropping systems in organic fields

Cropping system (Organic)	**Species**			
	Metaphire posthuma	***Lampito mauritii***	***Amynthas morissi***	***Travoscolides chengannur***
Basmati rice-Wheat	++	+	+	+
Basmati rice-Chick pea	++	+	+	-
Soyabean-Wheat	++	+	+	-
Moong-Wheat	++	+	+	-

Table 5. Species present in different cropping systems in conventional fields

Cropping system (Conventional)	**Species**			
	Metaphire posthuma	***Lampito mauritii***	***Amynthas morissi***	***Travoscolides chengannur***
Basmati rice-Wheat	+	+	+	-
Basmati rice-Chick pea	+	+	+	-
Soyabean-Wheat	+	+	+	-
Moong-Wheat	+	+	+	-

Table 6. Relative abundance of earthworms in different cropping systems under organic and conventional farming

	Cropping System	*Metaphire posthuma*	*Lampito mauritii*	*Amynthas morissi*	*Travascolides chengannur*
Organic	Basmati rice-Wheat	54.03	31.89	12.38	1.68
	Basmati rice-Chick pea	54.19	32.29	13.5	0
	Soyabean-Wheat	63.78	22.59	13.61	0
	Moong-Wheat	57.19	31.25	11.55	0
Conventional	Basmati rice-Wheat	61.81	30.64	7.53	0
	Basmati rice-Chick pea	63.7	39.34	7.1	0
	Soyabean-Wheat	61.69	14.43	23.88	0
	Moong-Wheat	54.77	27.94	17.27	0

Table 7. Diversity indices of earthworm species in different cropping systems: Simpsons index(D), Shannon Wiener index(H) and Evenness (E)

OCS	No. of Species	D	H	E
Basmati rice-Wheat	4	0.409	1.025	0.739
Basmati rice-Chick pea	3	0.416	0.967	0.881
Soyabean-Wheat	3	0.477	0.984	0.814
Moong-Wheat	3	0.438	0.932	0.849
CCS	**No. of Species**	**D**	**H**	**E**
Basmati rice-Wheat	3	0.482	0.855	0.778
Basmati rice-Chick pea	3	0.496	0.835	0.76
Soyabean-Wheat	3	0.458	0.919	0.837
Moong-Wheat	3	0.408	0.989	0.901

OCS, Organic Cropping System; **CCS,** Conventional Cropping System

Statistical analysis

To compare the abundance of earthworms in organic and conventional farming systems, a two-way ANOVA followed by a Tukey post hoc test was used. The soil data included physico-chemical characteristics of the soil. Further, the t-test analysis was done to analyze the soil parameters of the two selected farming systems i.e., Organic and Conventional farming systems.

Results and discussion

In this study, four earthworm species from two families, Megascolecidae and Octochaetidae, were identified. The earthworm species *Amynthas morrisi*, *Lampito mauritii*, and *Metaphire posthuma* belong to the family Megascolecidae while *Travoscolides chengannur* belongs to the Octochaetidae family. The different species of earthworms were reported in different crop fields. The relative abundance of *L. mauritii* and *A. morrisi* is relatively higher in organic fields than in conventional farming-based fields (Table 3). All four species of earthworms recorded during the study period were found in organic fields (Table 4) while *Travoscolides chengannur* was not observed in fields with conventional farming systems (Table 5). Dhar and Chaudhuri (2020) observed that changes in the environment, soil qualities, and other agricultural management methods have a significant impact on the number of earthworm species. Cai et al. (2020) have also reported the negative effects of chemical fertilizers and pesticides on the earthworm population. Therefore, the excessive use of chemical fertilizers and pesticides in the agriculture fields that adopt conventional farming techniques may reduce the relative abundance of earthworm species and their diversity.

Among all the species, the *M. posthuma* shows maximum relative abundance in organic soybean-wheat (Table 6). *L. mauritii*, is higher in both organic and conventional fields in basmati – chickpea as compared to other cropping systems. However, the overall relative abundance is higher in organic cropping farming systems than in conventional fields.

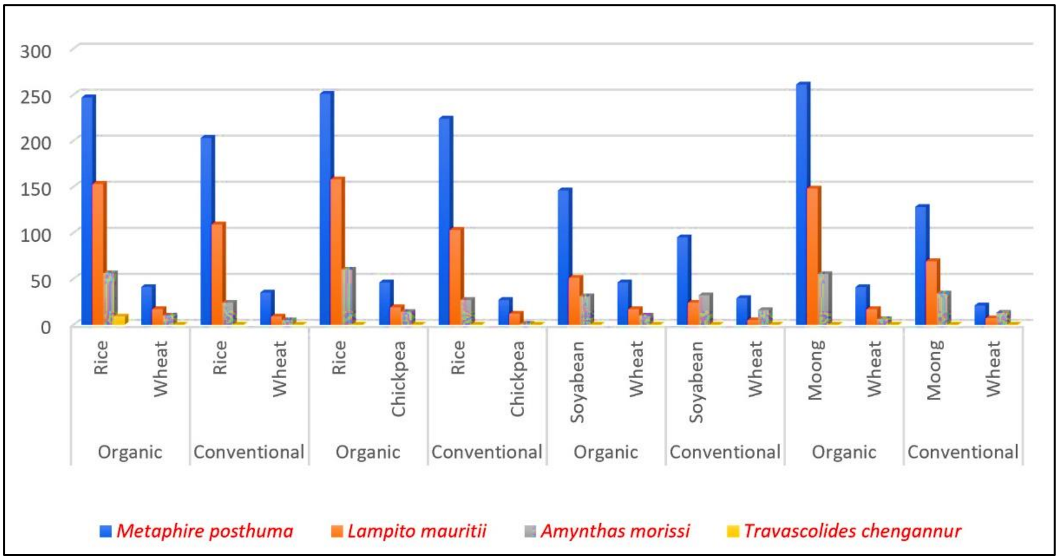

Fig. 1. Bar graph showing earthworm population in different cropping systems under organic and conventional farming

Further, the earthworm species, *A. morrisi* shows the highest inhabitation in organic farming systems. The least number of the same species has been found in the basmati-chickpea system when put under conventional farming. Interestingly, the species *T. chengannur* has only been isolated from the organic fields of basmati and wheat. It has a relative abundance of 1.68 which is overall the lowest among all other species.

The earthworm population in different cropping systems under organic and conventional farming is demonstrated in the bar graph. It demonstrates that the population of all earthworm species is relatively larger in organic farming than in conventional farming (Fig 1). Crittenden et al. (2014) also manifested that organic farming-based systems have higher biomass concentration as well as Shannon diversity in contrast to conventional farming. The diversity indices of earthworm species in different cropping systems such as Simpsons index (D), Shannon Wiener index (H) and Evenness (E) is shown in Table 7. The highest Shannon-Weiner diversity is being demonstrated in the organic basmati-wheat cropping system (1.025). Maximum evenness (0.881), is present in basmati-chickpea. However, the Simpson index among organic fields is fluctuating.

Conclusion

The diversity and abundance of earthworms were much higher in organic as compared to the conventional farming system. According to the findings of this study, conventional farming management practices that included increased amounts of chemicals such as fertilizers and pesticides had a negative impact on the earthworm population. As a result, the presence of high levels of chemical fertilizers and pesticides in typical soil could explain why there are fewer earthworm species in conventional agricultural systems. Further, *M. posthuma* was observed at maximum sampling sites due to its endogeic ecological nature. *T. chengannur* has been recorded for the first time in Punjab from the fields of organic farming system, PAU Ludhiana. Earthworms are crucial to the agro-ecosystem. They contribute significantly to soil aeration. The more the soil becomes porous, the higher the infiltration rate of water. Earthworms also synthesize humus by mineralizing the soil. They ingest the soil along with litter and their casts are full of decomposed matter. Therefore, Farmers must be educated about the potential impact of agrochemicals and their effect on earthworms. They should be made aware of the roles of earthworms in soil. In this way, the farmers can be encouraged to switch from conventional to organic farming practices. These approaches not only promote earthworm diversity and abundance, but they also nourish the soil with a variety of macro and micronutrients. The agriculture practices that are earthworm-friendly should be adopted for long-term soil productivity.

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Author Contributions

AK, RKA and NR conceived the concept, wrote and approved the manuscript.

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