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Original Article

Biodiversity of Earthworms with Special Reference to Tehsil Wazirabad, District Gujranwala, Punjab, Pakistan

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ABSTRACT

Earthworms are crucial soil invertebrates that are involved in the circulation of nutrients, humus formation, decomposition of organic matter and generation of soil texture. They play an important role as bioindicator of soil contamination. **Objective:** To investigate the biodiversity of earthworms in different habitats (Grassy lawns, croplands, marshy areas, ponds, edges of river and canals) of Tehsil Wazirabad, Punjab, Pakistan. **Methods**: A total number of four hundred and fifty (450) samples of earthworms were collected from above mentioned sites for a period of six months (March 2015 to August 2015), by hand sorting technique. Morphological details of all earthworm specimens collected from the designated areas were recorded and species were identified by using the systematic key. **Results:** During present investigation, six species; *Pheretima posthuma, P. lignicola, P. morrisi, Microscolex dubis, Aporrectodea longa* and *Notoscolex sacutarius* belonging to 4 genera and 2 families *(Megascolecidae, Lumbricidae)* were recorded. The distribution patterns of various earthworm species in the designated habitats shows that *Pheretima posthuma* is the most abundant species distributed in all sites; whereas, P. *lignicola* was least populated in the selected habitats. According to ecological grouping of reported earthworm species; Endogeic (50%) was the most dominant group followed by Epigeic (33%) and Anecic (17%). **Conclusions:** This study provided the base line data and much needed information about biodiversity of earthworms in Tehsil Wazirabad. This knowledge can be very useful in improving the soil conditions and agriculture gross production in investigated area.

INTRODUCTION

Earthworms are the crucial constituent of animal biomass in soil ecosystems [1, 2]. They can be regarded as keystone species considering their contribution as ecosystem engineers, as they perform key role in managing soil richness, water infiltration, improving plant development through biogeochemical cycling and adjusting the greenhouse gas discharge [3-6]. Through burrowing, throwing and mixing of soil with detritus (bioturbation) they alter the physicochemical properties of the upper layer of soil [7, 8]. Earthworms secrete variety of enzymes that change the chemical properties of different kinds of organic wastes [9]. They are not only utilized in the making of medicines but also an important source of food for moles, birds, snakes and woodcocks [10, 11]. They are involved in transferring of waste energy from lower trophic levels to higher ones [12]. Their influence on any ecosystem is usually described by their soil tunneling activities and litter feeding [13]. Ecosystems without earthworms exhibit slower degradation rate and thick layers of organic matter as compared to those ecosystems which are adapted to earthworms [14, 15]. Management of different earthworm populations is emerging as an important aspect for

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sustaining fertility and productivity of agro-ecosystems [16, 17]. The regional distribution pattern of earthworms (species dispersal and biodiversity) is greatly influenced by several abiotic and biotic factors such as land management history, temperature, pH, human pressure, soil properties, humidity and organic matter inputs [18, 19]. Earthworms are generally categorized into three basic ecological and functional groups based on their burrowing behavior, feeding habits and reproductive strategies [14]. (i) Epigeic species of earthworms inhabit and live on surface litter, (ii) Anecic species create deep vertical tunnels (2 meters) in mineral soil but feed on soil surface litter, (iii) Endogeic species construct horizontal burrows and feed mainly in the subsoil and rhizosphere [8]. Considering their role in the stabilization of soil ecosystem, substantial attention is required for the exploration of population dynamics, distribution, biodiversity and community structure of earthworms.

The present study was aimed to explore the diversity of earthworms and to identify various species collected from different habitats (croplands, grassy lawns, marshy areas, river banks, ponds and canal banks) of Tehsil Wazirabad, District Gujranwala. This is the first survey in tehsil Wazirabad and this information will help us in improving the soil conditions and agriculture production in this area.

METHODS

The present study was conducted in Tehsil Wazirabad. It is one of the four Tehsils of District Gujranwala in Punjab Province of Pakistan. It is situated at 32°26' North and 74°07' East on the banks of the river Chenab about 100 kilometers north of Lahore on the Grand Trunk Road [20]. It is 45 kilometers away from Sialkot, 30 kilometers from the District Gujranwala and nearly twelve (12) kilometers from Gujrat. The climate of the Tehsil Wazirabad is hot semi-arid and fluctuates throughout the year. The temperature of this area ranges between 44°C in summer to 7°C in winter. The highest precipitation is recorded from July to August during monsoon, whereas; the average rainfall is 25 millimeters per annum. In total seven sites of Tehsil Wazirabad were selected namely, Bella, Sohdra, Lawairi wala, Patoki, Talwara and Hari wala. The earthworm samples were collected from different habitats in these areas such as grassy lawns, croplands, marshy areas, ponds, edges of river and canals. These selected sites were visited many times for the sampling of earthworms. In total 450 earthworm samples were obtained from nominated sampling sites by simple hand sorting and digging method [21]. One square foot (ft2) hole was dug with spade and scraper in each designated site and earthworms were taken. Specimen and habitat details were noted carefully. Then the collected earthworm samples were placed in jars. After collection, all specimens were brought in the research lab of Institute of Zoology, University of the Punjab, Lahore, Pakistan. After washing and cleansing with tap water earthworms were placed in 10% ethyl alcohol (10-15 minutes) for dehydration. For hardening and killing they were kept in formalin solution (10%) for 24 hours. Finally, samples were preserved in 5% formalin solution for detailed morpho-anatomical identification. Before preservation width and length of earthworms were calibrated and their color was noted. For the detailed examination of earthworms dissecting microscope and magnifying glass were used. Then preserved samples of earthworms were identified with the help of taxonomic keys and published literature [22-25]. For identification, morphological characters such as shape of clitellum, color, shape of prostomium, position of spermatheca, number and position of genital papillae, position of dorsal pore, position of male pore, position of female pore were noted. Biodiversity of earthworms at all sites was assessed by Shannon–Weaver diversity index and Simpson index [26, 27]. All statistical analyses were performed by utilizing Microsoft Excel 2019 and SPSS version 21.0.

RESULTS

In the current study, we collected 450 earthworm samples from variety of areas of Tehsil Wazirabad, District Gujranwala, Punjab, Pakistan. We identified six (6) species of earthworms associated to four (4) genera and two (2) families (Table 1).

Table 1: List of earthworm species identified from Tehsil Wazirabad, Pakistan

Sr. No	Family	Genus	Species
1	Megascolecidae	*Pheretima*	*Pheretima posthuma*
2			*P. lignicola*
3			*P. morrisi*
4		*Microscolex*	*Microscolex dubius*
5		*Notoscolex*	*Notoscolex scutarius*
6	Lumbricidae	*Aporrectodea*	*Aporrectodea longa*

Identification (up to species level) was made possible by considering their morphological characters as listed in Table 2 with the help of above-mentioned identification keys and published literature

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Table 2: Taxonomic Characters of Identified Species of earthworms

Taxonomic characters	*N. scutarius*	*P. morrisi*	*P. lignicola*	*P. posthuma*	*A. longa*	*M. dubis*
Body Shape	Cylindrical	Cylindrical	Cylindrical	Cylindrical	Cylindrical	Cylindrical
Color	Greyish brown or yellowish	Blackish brown	Olive green	Reddish dark brown to brownish grey	Brown on upper and pale underside	Pale yellow
Body Length	68-90 mm	60-120 mm	50-70 mm	55-110 mm	90-170 mm	80-130 mm
Breadth	4-5 mm	3-4 mm	3.5-4 mm	3-4.5 mm	4-6 mm	3-4 mm
Number of Segments	115-140	85-124	90-105	70-120	100-150	100-115
Shape of Prostomium	Epilobous	Epilobous	Epilobous	Tanylobous	Epilobous	Epilobous
Arrangement of Body Setae	Perichaetine	Perichaetine	Perichaetine	Perichaetine	Lumbricine	Perichaetine
Color of Clitellum	Brown	Dark brown	Green	Brown	Brown	Orange
Shape of Clitellum	Annular	Annular	Annular	Annular	Annular	Annular
Position of Clitellum	xiv-xvi	xiv-xvi	xiv-xvi	xiv-xvi	xxvii-xxxv	xiv-xvi
Length of Clitellum	3-4 mm	3-4 mm	4-5 mm	3-5 mm	5 mm	3-4 mm
Width of Clitellum	3 mm	3-5 mm	2.5-3.4 mm	2-4 mm	4 mm	3 mm
Length before Clitellum	1 cm	1 cm	1 cm	1 cm	More than 1 cm	1 cm
Position of Male Pore	Pair on xviii	Pair on xviii	Pair on xviii	Pair on xviii	Pair on xviii	Pair on xvii
Position of Female Pore	Single on xiv	Single on xiv	Single on xiv	Single on xiv	Single on xiv	Single on xiv
Dorsal Pore	13/14	10/11	12/13	12/13	Not visible	14/15
No. of Spermatheca	Two on 7/8, 8/9	Wanting	Wanting	Absent	Two on 9/10, 10/11	Absent
Genital Papillae	On xvii and xix	On xvii and xix	On xvii and xix	On xvii and xix	On xvii and xix	On xvii and xix

Pheretima posthuma (n=164) was observed as most prevalent earthworm species in all selected sites of Tehsil Wazirabad, whereas, *Pheretima lignicola* (n=17) was noted as least abundant species (Figure 1).

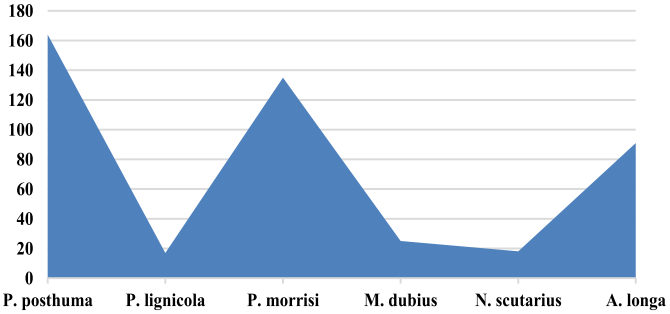

Figure 1: Relative abundance of earthworm species collected from Tehsil Wazirabad

Pheretima (3 species) was observed as the most diverse genus while, other 3 genera were recorded with one species each (Figure 2).

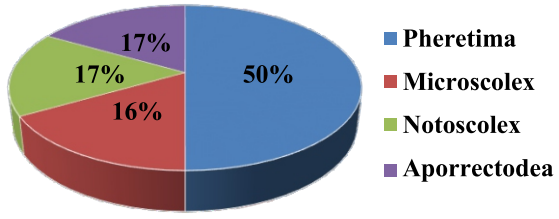

Figure 2: Percentage representation of earthworm genera identified from Tehsil Wazirabad

Among the various visited habitats from 6 selected areas (Bella, Sohdra, Lawairi wala, Patoki, Talwara and Hari wala), maximum diversity of earthworms was recorded in grassy lawns (5 species), whereas, minimum diversity was observed at canal banks (2 species). *Pheretima posthuma* and *Pheretima morrisi* were discovered in all habitats (Table 3).

Table 3: Species diversity of earthworms in various habitats.

Habitat	Number of discovered species	Names of the discovered species
Crop lands	3	*P. posthuma, A. longa, P. morrisi*
Grassy lawns	5	*M. dubius, P. posthuma, A. longa, P. morrisi, P. lignicola*
Marshy areas	3	*P. morrisi, P. posthuma, A. longa*
Edges of river	3	*P. morrisi, P. posthuma, A. longa*
Edges of ponds	4	*P. morrisi, P. posthuma, A. longa, N. scutarius*
Canal banks	2	*P. posthuma, P. morrisi*

The identified earthworm species were categorized into 3 ecological groups. Out of six (6) identified species, two (2) species were Epigeic (33%), three (3) species were endogeic (50%), whereas, only one species (17%) belonged to Anecic (Table 4).

Table 4: Ecological classification of identified earthworms

Sr. No	Categories	Identified species
1	Epigeic	*Pheretima posthuma, Pheretima morrisi*
2	Endogeic	*Notoscolex scutarius, Microscolex dubius, Pheretima lignicola*
3	Anecic	*Aporrectodea longa*

Shannon-Weaver diversity index (H), exhibited maximum

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diversity of earthworms (0.33) in all habitats of selected Site-1 (Bella), whereas, minimum value (0.23) was manifested for Site-6 (Hari wala). Similarly, Simpson index of dominance (D), calculated maximum value (0.04) at Site-1 and minimum value (0.01), at site-6. In contrast, Simpson index of diversity manifested highest value (0.99) at site-6 and minimum value (0.95) at site-1 (Figure 3).

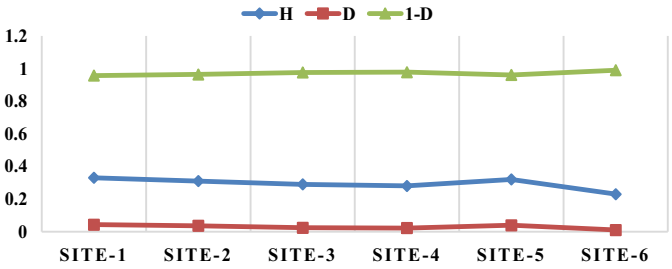

Figure 3: Diversity indices of earthworm species identified from all sites of Tehsil Wazirabad

(Site-1=Bella, Site-2=Sohdra, Site-3=Lawairi wala, Site 4=Patoki, Site-5=Talwara, Site-6=Hari wala) H (Shannon-Weaver diversity index), D (Simpson index of dominance), 1-D (Simpson index of diversity)

DISCUSSION

The present investigation was carried out in Tehsil Wazirabad, District Gujranwala. It was divided into six (6), different sub-regions (Bella, Hari wala, Lawairi wala, Patoki, Talwara and Sohdra). In these areas variety of habitats (Crop lands, grassy Lawns, marshy areas, Edges of river, canal banks and edges of ponds), were explored for the biodiversity of earthworms. We were able to identify 6 species of earthworms belonging to 2 families (Lumbricidae, Megascolecidae) and 4 genera (*Pheretima, Microscolex, Notoscolex and Aporrectodea*), as the presence of these families in Asian countries is already reported by earlier researchers [28, 29, 2]. Megascolecidae was found as most diverse and abundant family followed by Lumbricidae, these findings were in accordance with previous studies [30]. *Pheretima morrisi* and *Pheretima posthuma* were noted as most abundant earthworm species. Similar results were described by previous authors [31-33]. Maximum diversity of earthworms (5 species), was observed in grassy lawns and home gardens. Higher content of soil moisture due to regular watering along with availability of excessive organic matter could be the cause of more diversity of earthworms in lawns and house gardens. Najar and Khan in 2011, also reported more earthworm diversity in the gardens of Jammu and Kashmir, while Garg and Jhulka in 2017, observed similar pattern in the Trans-Gangetic Plains of Haryana [17, 34]. Endogeics was the dominant group displaying a species composition of 50%, whereas, Epigeics share 33% of the earthworm species and Anecics was the least common group comprising of 17% of the total identified species.

CONCLUSIONS

Present study provided the base line data and much needed information about biodiversity of earthworms in Tehsil Wazirabad. This knowledge can be very useful in improving the soil conditions and agriculture gross production in investigated area. Among the six identified species *Pheretima posthuma* was noted as the most abundant species present in all kinds of habitats. Grassy lawns and home gardens proved to be very productive areas for the earthworms. Further investigations are required to explore the biodiversity of earthworms in different areas of Pakistan.

Authors Contribution

Conceptualization: MAR
Methodology: AH
Formal analysis: SAH
Writing-review and editing: UZ, MAR, AH

All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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REFERENCES

[1] Blouin M, Sery N, Cluzeau D, Brun JJ, Bédécarrats A. Balkanized research in ecological engineering revealed by a bibliometric analysis of earthworms and ecosystem services. Environmental Management. 2013 Aug; 52: 309-20. doi: 10.1007/s00267-013-00798.

[2] Raja IA, Ehsan N, Rana N, Sarwar A. Impact of soil pollutants on diversity and abundance of earthworms in cauliflower crop. Journal of Entomology and Zoology Studies. 2017; 5(4): 1007-12.

[3] Lavelle P, Charpentier F, Villenave C, Rossi JP, Derouard L, Pashanasi B *et al.* Effects of earthworms on soil organic matter and nutrient dynamics at a landscape scale over decades. Earthworm Ecology. 2004 Mar; 2: 145-60. doi: 10.1201/9781420039719.pt4.

[4] Bastardie F, Capowiez Y, Cluzeau D. 3D characterisation of earthworm burrow systems in natural soil cores collected from a 12-year-old pasture. Applied Soil Ecology. 2005 Sep; 30(1): 34-46. doi: 10.1016/j.apsoil.2005.01.001.

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DOI: https://doi.org/10.54393/mjz.v5i01.85

[5] Lubbers IM, Van Groenigen KJ, Fonte SJ, Six J, Brussaard L, Van Groenigen JW. Greenhouse-gas emissions from soils increased by earthworms. Nature Climate Change. 2013 Mar; 3(3): 187-94. doi: 10.1038/nclimate1692.

[6] Rafique A and Rana SA. Species association of some earthworms in the agroecosystem of Faisalabad and Sargodha. Pakistan Journal of Agriculture Sciences. 2001; 38: 3-4.

[7] Eisenhauer N. The action of an animal ecosystem engineer: Identification of the main mechanisms of earthworm impacts on soil microarthropods. Pedobiologia. 2010 Oct; 53(6): 343-52. doi: 10.1016/j.pedobi.2010.04.003.

[8] Ferlian O, Eisenhauer N, Aguirrebengoa M, Camara M, Ramirez-Rojas I, Santos F, Tanalgo K *et al.* Invasive earthworms erode soil biodiversity: A meta-analysis. Journal of Animal Ecology. 2018 Jan; 87(1): 162-72. doi: 10.1111/1365-2656.12746.

[9] Rajiv KS Sunil H, Sunita A, Ravi A and Emilio C. Vermiculture and waste management: study of action of earthworms *Elsiniafoetida, Eudriluseuginae* and *Perionyx* excavates on biodegradation of some community wastes in India and Australia. Earthworms and Environmental Sciences. 2004; 22: 261-8.

[10] Symondson WO, Glen DM, Erickson ML, Liddell JE, Langdon CJ. Do earthworms help to sustain the slug predator *Pterostichus melanarius* (*Coleoptera: Carabidae*) within crops? Investigations using monoclonal antibodies. Molecular Ecology. 2000 Sep; 9(9): 1279-92. doi: 10.1046/j.1365-294x.2000.01006.x.

[11] Cooper EL, Balamurugan M, Huang CY, Tsao CR, Heredia J, Tommaseo-Ponzetta M *et al.* Earthworms dilong: ancient, inexpensive, noncontroversial models may help clarify approaches to integrated medicine emphasizing neuroimmune systems. Evidence-Based Complementary and Alternative Medicine. 2012 Jan; 2012. doi: 10.1155/2012/164152.

[12] Sivakumar S, Prabha D, Barathi S, Nityanandi D, Subbhuraam CV, Lakshmipriya T *et al.* The influence of the earthworm Lampito mauritii (Kinberg) on the activity of selected soil enzymes in cadmium-amended soil. Environmental Monitoring and Assessment. 2015 Mar; 187: 1-8. doi: 10.1007/s10661-014-4253-0.

[13] Edwards CA. The importance of earthworms as key representatives of the soil fauna. Earthworm Ecology. 2004 Mar; 2: 3-11. doi: 10.1201/9781420039719.pt1.

[14] Hendrix PF and Bohlen PJ. Exotic earthworm invasions in North America: ecological and policy implications: expanding global commerce may be increasing the likelihood of exotic earthworm invasions, which could have negative implications for soil processes, other animal and plant species, and importation of certain pathogens. Bioscience. 2002 Sep; 52(9): 801-11. doi: 10.1641/0006-3568(2002)052[0801:EEIINA]2.0.CO;2.

[15] Hendrix PF, Callaham Jr MA, Drake JM, Huang CY, James SW, Snyder BA *et al.* Pandora's box contained bait: the global problem of introduced earthworms. Annual Review of Ecology, Evolution, and Systematics. 2008 Dec; 39: 593-613. doi: 10.1146/annurev.ecolsys.39.110707.173426.

[16] Whalen JK, Parmelee RW, Edwards CA. Population dynamics of earthworm communities in corn agroecosystems receiving organic or inorganic fertilizer amendments. Biology and Fertility of Soils. 1998 Sep; 27: 400-7. doi: 10.1007/s003740050450.

[17] Garg N and Julka JM. Biodiversity of Earthworms in Trans-Gangetic Plains of District Yamuna Nagar, Haryana. Voyager. 2017 Dec; 124-32.

[18] Callaham Jr MA, Hendrix PF, Phillips RJ. Occurrence of an exotic earthworm (*Amynthas agrestis*) in undisturbed soils of the southern Appalachian Mountains, USA: The 7th International Symposium onn Earthworm Ecology. Cardiff, Wales, 2002. Pedobiologia. 2003 Jan 1; 47(5-6): 466-70. doi: 10.1016/S0031-4056(04)70223-1.

[19] Suthar S. Earthworm biodiversity in western arid and semiarid lands of India. The Environmentalist. 2011 Mar; 31(1): 74-86. doi: 10.1007/s10669-011-9308-y.

[20] Meyer S and William A. 1922. Imperial Gazetteer of India, 24: 380.

[21] Lalthanzara H, Zothansanga C, Lalchhanhima M, Kumar NS, Ngukir J, Kimsing A *et al.* Diversity and new records of earthworms in Arunachal Pradesh, Northeast India. Journal of Environmental Biology. 2020 Jul; 41(4): 874-83. doi: 10.22438/jeb/4(SI)/MS_1921.

[22] Stephenson J. Oligochaeta, Fauna of British India Series. London. UK. 1923; 507.

[23] Gates GE. Burmese earthworms: an introduction to the systematics and biology of megadrile oligochaetes with special reference to Southeast Asia. Transactions of the American Philosophical Society. 1972 Jan; 62(7): 1-326. doi: 10.2307/1006214.

[24] Julka JM. fauna of India and the adjacent countries. 1988. 1-400.

[25] Halder KR, Dhani S, Mandal CK. On some earthworms present in unnamed collections of zoological survey

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DOI: https://doi.org/10.54393/mjz.v5i01.85

of India. Records of the Zoological Survey of India. 2007 Sep; 107(3): 79-93. doi: 10.26515/rzsi/v107/i3/2007/159128.

[26] Shannon CE and Weaver W. The mathematical theory of information. Urbana: University of Illinois Press; Illinois, USA; 1949.

[27] Simpson EH. Measurement of diversity. Nature; 1949. doi: 10.1038/163688a0.

[28] Reynolds JW and Wetzel MJ. Terrestrial Oligochaeta (Annelida: Clitellata) in North America north of Mexico. Megadrilogica. 2004 Mar; 9(11): 71-98.

[29] Fatima Jalal FJ, Qureshi JI, Bokhari SA, Asma Haque AH, Khalid ZM, Rana SA. Contribution of earthworms to enhance fertility in selected orchards of Faisalabad district. International Journal of Biosciences. 2014; 5(9): 75-84. doi: 10.12692/ijb/5.9.75-84.

[30] Hussain M, Liaqat I, Ali S, Aftab N, Ulfat M, Naseem S *et al*. Diversity and Abundance of Delineated Earthworm (Annelida: Clitellata) in Pakistan: A Review. Journal of Oleo Science. 2022; 71(6): 834-839. doi: 10.5650/jos.ess22018.

[31] Abdul Ghafoor AG, Muhammad Hassan MH, Alvi ZH. Biodiversity of earthworm species from various habitats of District Narowal, Pakistan. International Journal of Agriculture and Biology. 2008; 10: 681-4.

[32] Sial N, Abid S, Shahzad MI, Hashim S, Kirmani F, Shafique S *et al*. Diversity of earthworms in district Bahawalpur, Punjab, Pakistan. Wulfenia Journal. 2017 ; 24(4): 170-4.

[33] Aziz S, Ehsan N, Latif F, Ali MS, Abdullah S. Comparison of Biodiversity and Abundance of Earthworms in Maize Croplands, Irrigated with Sewage and Canal Water of District Faisalabad, Pakistan. Journal of Bioresource Management. 2023; 10(1): 16.

[34] Najar IA and Khan AB. Factors affecting distribution of earthworms in Kashmir Valley: a multivariate statistical approach. In: Proceedings of the Zoological Society. 2014 Dec; 67(2): 126-135. doi: 10.1007/s12595-013-0081-4.

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