International Journal of Forest Sciences (2023). 3(2): 57-66

Review **Open Access**

Diversity and antibacterial activity of earthworm species-a review

Muhammad Atif Kamran[1*] and Asma Nawaz[2]

1. Department of Zoology, University of Sargodha, Sargodha.
2. Department of Zoology, Government College University, Faisalabad.

***Corresponding author e-mail:** atifpetangi45@gmail.com

SUMMARY

Earthworms significantly influence the efficient function of the soil ecosystem. They feed on dead and decaying matter as well as on plant material and help to recycle nutrients. They are also known as Farmer's Friends because they enhance soil fertility. Various medical treatments have included the use of earthworms. Earthworm paste has the potential for the development of novel medication. Distinct species of earthworms revealed the mechanism of antibacterial activity. Other bioactive compounds, including amylase, protease, and cellulase found in the earthworm paste have shown the potential to restrain the growth of fungi and bacteria. This work focused on studying antibacterial properties associated with different earthworm species which may have indirect applications for the treatment of different diseases linked with microbes.

Keywords: Antimicrobial Activity, Earthworm, Antibacterial Activity

Citation: Kamran, M.A., A. Nawaz. 2023. Diversity and antibacterial activity of earthworm species. International Journal of Forest Sciences. 3:56-66.

Received: October, 2022**; Accepted**: May, 2023

INTRODUCTION

The biological diversity of earth usually has large contribution to the real productiveness of agrarian systems. The main part of natural agricultural systems represents soil communities and thereby has important contribution in conserving the services of ecosystem for the welfare of human beings (Decaens, 2010). Earthworms are incredibly significant soil micro invertebrates as contribute a huge part of the whole biomass of micro invertebrates occur in land. More than 80 percent of earthworms are present in semitropic, tropics and moderate area (Nainawat and Nagendra, 2001). Approximately 3,627 species of earthworms are identified globally. Earthworms are also known as ‘‘Ecosystem Engineers’’ (Kooch and Jalilvand, 2008).

Earthworms are significant terrestrial invertebrates' members of the Phylum Annelida, Class Chaetopoda and Order Oligochaeta. In the duration of pre-Cambrian era earthworms rose approximately six hundred million years ago (Piearce *et al.*, 1990). Earthworms are found in various niche, having efficient role, through performing chemical and physical modifications in land surface. These modifications lead to enhancement in richness of soil. A proposal about management of valid soil through special importance on the function of inhabitants of soil likely "earthworms",

in richness of soil, is much significant in sustaining ecology balance (Shuster *et al*., 2000).

Earthworms are smooth-bodied, nocturnal and saprobes invertebrates of agrarian ecosystem. They are also considered as one of the significant macro creatures of the soil biology. In the Animal kingdom they have recognized place. Earthworms are successful terrestrial inhabitants. The earthworm body is separated into a series of sections which are arranged in regular way (Hama, 1959). Due to these internal and external divisions of segments makes the body of earthworm flexible and well-developed muscular structure. Earthworms are the earliest array of animals improved and entire digestive system. They have well developed closed circulatory system which have hemoglobin in the function of "plasma" as carrier of carbon dioxide and oxygen (Monahan Earley *et al.*, 2013).

Earthworms are cosmopolitan in distribution, but uncommon in soil which have uniform snow and ice, ranges of mountain and region which is entirely have no soil and herbage (Edwards et al., 1996). The species which are cosmopolitan in distribution are known as peregrine, those species that are not capable to distribute successful manners to areas (Edwards and Lofty, 1977).

Earthworms are most vital organisms of soil, and they contribute a huge portion of whole biomass of invertebrates. They enhance the grade of soil and yields of plants (Edwards et al., 1980; Darwin, 1882; Lee, 1985). Earthworms have vital contribution in the formation and richness of "soil" is well supported and recognized by documents (Darwin, 1882; Edwards *et al.,* 1995; Kale, 1998; Lalitha *et al.,* 2000).

The major natural action of earthworms includes the intake of soil, making the mixture of distinct ingredients of soil (Jairajpuri, 1993). Earthworms have vital function in the decay of "organic matter" and "metabolism" of soil through food intake, disintegration of soil particles, aeration, overturn and distribution (Shuster *et al.,* 2000). According to Aristotle the earthworms were regarded as "the intestines of earth and the restoring agents of soil fertility" (Ismail, 2005; Ansari and Ismail, 2012). The effective population of earthworms represents that there is the huge population of organisms are present in this soil like spiders, insects, and other organisms and hence show the good health of soil (Edwards *et al.,* 1995; Tomlin *et al.,* 1995; Shuster *et al.,* 2000; Lachnicht and Hendrix, 2001; Ismail, 2005; Ansari and Ismail, 2008; Ansari and Sukhraj, 2010).

Earthworms have various roles in biology and fertility of soil (Clive, 2004). They are also known as bioreactor of nature they change the organic waste into organic muck. Earthworms are also helpful in soil reformation, improvement of soil and management of organic waste (Syers *et al.,* 1979; Jerez *et al*., 1988; Harender and Bhardwaj, 2001). Nitrogen-fixing bacteria are present in the cast and alimentary canal of earthworms which increase the activity of nitrogenase enzymes and increased the rates of N-fixation. When the activity of cast compared with soil, they show the greater amount of nitrogen fixation in cast (Simek and Pizl, 1989). They also known as the English red worm (Symondson *et al*., 2000; William *et al.,* 2006). Some enzymes secreted by earthworm like chitinases, amylases, proteases, lipases and cellulases which involve in enhancement of biochemical transformation of the proteinaceous and cellulosic and materials in the various organic wastes. These organic wastes release from gardens, homes, farms and dairies (Sinha *et al.,* 2002).

Earthworms convert the organic matter into minerals and thereby discharge the nutrients in available forms which are then absorbed by the plants (Martin, 1991; Edwards *et al.,* 1996). During the cellular and humoral defense mechanisms sometimes, earthworms give response to the infection of microbes and secrete antimicrobial proteins. The skin of earthworm secretes the humoral defense proteins which help in humoral defense response. Earthworms have significant role in the destruction of bacteria and with other significance of disease (Cooper *et al.,* 2004).

The earthworm powder given orally, it shows the thrombolytic effect and maintains an effect of inhibition on platelet aggregation, an effect of anticoagulation (Mihara *et al*., 1996). The earthworms gain the attention of several scientists due to the biotechnological development and presence of bioactive compound in their body (Fang, 1999; Shen, 2010). Earthworms are hermaphrodites (Harender and Bhardwaj, 2001). Mucus has significant role in earthworm feeding, maintenance of salt and fluids, defense and reproductive process (Cortez and Bouche,1987; Heredia *et al.,* 2008).

Rafiq (2000) and Mannan *et al*. (1994) reported earthworm species from Lahore. They studied that type of soil, the season, amount of humidity, vegetation and temperature during daytime and importantly effected population density of the earthworm from Lahore. From Japan the importantly species were named as *Megascolex sieboldin, and Megascolex schmardae*, all identified by Horst (1883) while twenty-seven species of earthworm were also reported from Japan from material in the collectionsof the Leiden Museum Japan (Goto and Hatai, 1899).

Some studies had been carried out to evaluate the diversity of earthworm in Punjab (Rana *et al.,* 2000; Jalal, 1998; Khatoon, 1996; Khanum, 1999), European (Mackay and Kladivko, 1985; Rafique and Rana, 2001; Bohlen *et al.,* 1995). Since 1340 AD earthworms have been used in many medicines for many diseases (Hossam *et al.,* 2012).

Earthworm has been introduced in drug as “anti-inflammatory”, “antipyretic” and “analgesic agent” (Prakash and Gunasekaran, 2010). Through prevention of uptake of large amount of glucose, it shows the anticancer effect (Balamurugan *et al.,* 2009). Certain study had been done on anti-microbial substances, which included active enzymes (Wenli *et al.,* 2011). It is also reported that excretion from the surface of earthworm were showed the strong “antimicrobial activity” (Cooper and Balamurugan, 2010).

Some studies had been made on the medicinal properties of earthworm (Shobha and Kale, 2007) like antimicrobial (Bauer *et al.,* 1966), antibacterial, fibrinolytic, anticoagulative, antimicrobial, anticancer, (Cooper *et al*., 2012), bacteriostatic (Cooper *et al*., 2004; Popovic *et al*., 2005), proteolytic (Nakajima *et al*., 1993; Wang *et al*., 2003), cytolytic (Popovic *et al*., 2001; Matausic-Pisl *et al*., 2011) and mitogenicity activity (Hrzenjak *et al*., 1993). It is also reported that the celomic fluid of *Eisenia* and *Lumbricus* some molecules are present which protect earthworm from microorganisms (Valembois *et al*., 1982; Stein *et al.,* 1982). This activity is imputed to some proteins, such as lysozyme and fetidins (Hirigoyenberry *et al*., 1990; Milochau *et al*., 1997). Some studies had also done about the antimicrobial factors in the tissue of earthworm (Cho *et al*., 1998; Popovic *et al*., 2005). Some work is also done by Gosh on earthworm diversity (Julka, 1993).

Some observations were also made by Sarwar Jahan on the diversity of earthworm (Sarwar *et al.,* 2005). Bouche (1977) described morpho-ecological categories of earthworm. Somestudies have been done on the composition of structures in different communities of earthworms in the several types of agrarian ecosystem (Fragoso *et al*., 1999). Review of literature exposed the relation of earthworm population to different soil types is known (Dash and Patra, 1977; Fragoso *et al*., 1999). Julka (1993) reported the ecological aspects of Indian earthworms with their "vermicomposting technique". In the Egypt from few places the composition of earthworm community was reported by El-Duweini *et al*. (1965). The richness and dispersal patterns of earthworms were estimated in Meriut coastal desert region in Egypt by Ghabbour and Shakir (1982). A report has made on the fauna of earthworm in Great American Desert and adjoining areas by Gates (1967). The diversity and pattern of distribution of earthworm communities in Asia are well noted (Stephenson, 1921; Stephenson, 1923;Templeton, 1844; Gates, 1945; Dash and Patra, 1977;Senapati *et al.*,1979; Julka, 1985;Julka and Senapati, 1987; Julka, 1988; Julka, 1996; Kale and Bano, 1991; Bhardwaj, 2001; Julka and Paliwal, 2005).

According to another report that in some tribe of Australia and New Zealand earthworms are used as food (Jairajpuri, 1993). Some studies reveals that the body of earthworms contain acids like linoleic, arachidonic acids that are used for the reproduction and growth of animals (Kale, 2005) so, the dried powder of earthworms are used in animal feed industries. Earthworms are affected by type of soil and quality (Guild, 1948).

Antitumor activities of earthworm fibrinolytic enzyme on human hepatoma cells were studied by (Hong, 2007). Anenzyme Lumbricin was discovered from the earthworm by Cho *et al.*(1998). According to few reports that earthworms are used for the mineralization of organic matter. During this mineralization process they release some nutrients in soil that can be taken up by the plants (Edwards et al., 1996).Some studies have made on the effect of earthworms on nitrogen cycling and nitrogen in soil (Lee, 1983). According to him, nitrogenous products of earthworm metabolism like urine, mucoproteins and dead tissues of earthworms are returned to the soil through casts. The population of microbes in casts ofearthworms is greater in number as compared to the surrounding soil (Haynes *et al.*, 1999).

Shobha and Kale (2007) demonstrated the antimicrobial potency and anti-inflammatory activity of *Eudrilus eugeniae* of earthworm extracts. Julka (1993) described some ecological features of Indian earthworms and describe their vermicomposting technique. Sarwar *et al. (*2005)also made some studies on earthworm according to him that the higher number of earthworms were founded near freshwater bodies and lower numbers were found in saline area (Sarwar et al., 2005). The distribution of earth worms with their mature and immature numbers in their most favorable period of life were studied by (Evans and Lavelle, 1978).

Some studies have been made on the aneceictype of earthworm in coconut field by Bouche (1977). Structural composition of earthworm's communities deviate according to their type of agro ecosystem reported by Fragoso *et al*.(1999). Lumbricin from the earthworm is identified by Cho*et al*. (1998). Few reports are available about the microbial population in the casts of earthworms are greater in number as compared to surroundings soil (Haynes *et al*., 1999).

Some laboratory and microcosm studies are also available about the plant growth, nutrient availability with the occurrence of earthworm (Scheu 1987; Scheu and Parkinson, 1994). In many laboratory studies the comparison of earthworm and casting were also done in brief period (Lunt and Jacobsen, 1944; Syers *et al*., 1979; Lee, 1985; Edwards and Bohlen, 1995; Parkin and Berry, 1994; Scheu, 2003; Edwards,2004). Although, earthworms are documented in the earth, they are neglected organisms in subcontinent. Many Zoologists have reported the significance of "earthworms" in "fertility" of soil such as (Nijhawan and Kanwar, 1952; Bhatti ,1962; Edwards and Lofty, 1977; Ghafoor *et al.*, 1988; Ghafoor and Qureshi, 1999; Naheed *et al*., 2003) have made the list of fauna of a few localities in Pakistan.

REFERENCES

Ansari, A. A., and Ismail, S. A. 2008. Reclamition of sodic soils through Vermitechnology. Pakistan J. Agric. Res. 21: 1-4.

Ansari, A. A., and Ismail, S. A. 2012. Role of earthworms in vermitechnology. Journal of Agricultural Technology. 8: 403-415.

Ansari, A. A., and Kumar, S. 2010. Effect of vermiwash and vermicompost on soil parameters and productivity of okra (Abelmoschus esculentus) in Guyana. Current Advances in Agricultural Sciences (An International Journal). 2: 1-4.

Balamurugan, M., Parthasarathi, K., Cooper, E. L., and Ranganathan, L. S. 2009. Anti-inflammatory and anti-pyretic activities of earthworm extract—Lampito mauritii (Kinberg). Journal of ethnopharmacology. 121: 330-332.

Bauer, A. W. M. M., Kirby, W. M. M., and Sherris, J. C. T. 1966. turck, Turck M. Antibiotic susceptibility testing by a standardized single disk method. American journal of clinical pathology. 45: 493.

Bhardwaj, P. 2001. Earthworm biodiversity and its potential in reduction of organic materials (Doctoral dissertation, PhD Thesis, Jai Narain Vyas University, Jodhpur, India. p 256).

Bhatti, H., K.1962. Earth worms of Lahore-Pakistan. J. Res.,14: 16–23.

Bohlen, P., J.Edwards, W. M and Edwards, C. X. 1995. Earthworm community structure and diversity in experimental agricultural water sheds in northeastern Ohio. Plant and Soil. 233-239

Bouche, M., B.1977. Stratagies lumbriciennes. Ecological Bulletin (Stockh). 25: 122-132.

Cho, J. H., Park, C. B., Yoon, Y. G., and Kim, S. C. 1998. Lumbricin I, a novel proline-rich antimicrobial peptide from the earthworm: purification, cDNA cloning and molecular characterization. Biochimica et Biophysica Acta (BBA)-Molecular basis of disease. 1408: 67-76.

Clive, A., E. 2004. Earthworm ecology, 2nd ed., New York: CRC Press LLC. 3–4.

Cooper, E. L., and Balamurugan, M. 2010. Unearthing a source of medicinal molecules. Drug Discovery Today. 15: 966-972.

Cooper, E. L., Balamurugan, M., Huang, C. Y., Tsao, C. R., Heredia, J., Tommaseo-Ponzetta, M., and Paoletti, M. G. 2012. Earthworms dilong: ancient, inexpensive, noncontroversial models may help clarify approaches to integrated medicine emphasizing neuroimmune systems. Evidence-Based Complementary and Alternative Medicine, 2012.

Cooper, E. L., Hrzenjak, T. M., and Grdiša, M. 2004. Alternative sources of fibrinolytic, anticoagulative, antimicrobial and anticancer molecules. International Journal of Immunopathology and Pharmacology. 17: 237-244.

Cortez, J., and Bouché, M. 1987. Composition chimique du mucus cutané de Allobophora chaetophora chaetophora (Oligochaeta: Lumbricidae). Comptes rendus de l'Académie des sciences. Série 3, Sciences de la vie. 305: 207-210.

Darwin, C. 1892. The formation of vegetable mould, through the action of worms: with observations on their habits.

Dash, M. C., and UC, P. 1977. Density, biomass and energy budget of a tropical earthworm population from a grassland site in Orissa, India.

Decaëns, T. 2010. Macroecological patterns in soil communities. Global Ecology and Biogeography. 19: 287-302.

Edwards, C. A., and Bohlen, P. J. 1996. Biology and ecology of earthworms (Vol. 3). Springer Science and Business Media.

Edwards, C. A., and Lofty, J. R. 1977. Biology of Earthworms, Chapman and Hall. London, UK.

Edwards, C. A., and Lofty, J. R. 1980. Effects of earthworm inoculation upon the root growth of direct drilled cereals. Journal of Applied Ecology. 533-543.

Edwards, C. A., Bohlen, P. J., Linden, D. R., and Subler, S. 1995. Earthworms in agroecosystems. Earthworm ecology and biogeography in North America. 185-213.

Edwards., CA (ed) 2004.Earthworm ecology, 2nd edn. CRC Press, Boca Raton FL. 456.

El-Duweini, A. K., and Ghabbour, S. I. 1965. Population density and biomass of earthworms in different types of Egyptian soils. Journal of Applied Ecology. 271-287.

Fang, Y. S. 1999. Eisenia fetida fibrinolytic enzymes research VIII: determination of fibrinolytic enzymes active components. Heilong Jiang Journal of Medicine. 12: 263-264.

Fragoso, C., Lavelle, P., Blanchart, E., Senapati, B. K., Jimenez, J. J., Martinez, M. D. L. A., and Tondoh, J. 1999. Earthworm communities of tropical agroecosystems: origin, structure and influence of management practices. Earthworm management in tropical agroecosystems. 27-55.

Gates, G. E. 1945, April. On some Indian earthworms. In Proceedings/Indian Academy of Sciences. 21: 208-258).

Gates, G. E. 1967. On the earthworm fauna of the Great American Desert and adjacent areas. The Great Basin Naturalist. 27: 142-176.

Ghabbour, S. I., SI, G., and SH, S. 1982. Population parameters of soil mesofauna in agro-ecosystems of the mariut region, Egypt. I: Under day-farmed almond.

Ghafoor, A., and Qureshi, J. L. 1999. Five new records of earthworms from Faisalabad. Pakistan International Journal Agricultural Science. 135: 74â.

Ghafoor, A., Qureshi, J. I., and Chaudhry, M. S. 1988. Earthworms of Faisalabad Division [Pakistan]. Pakistan Journal of Agricultural Sciences (Pakistan).

GOTO, S., and HATAI, S. 1899. NEW OR IMPERFECTLY KNOWN SPECIES OF EARTHWORMS. NO. 2. Annot. Zool. Japon. 3: 13-24.

Guild, B. W. M. 1948. Studies on the relationship between earthworms and soil fertility: the effect of soil type on the structure of earthworm populations. Annals of Applied Biology. 35: 181-192.

Hama, K. 1959. Some observations on the fine structure of the giant nerve fibers of the earthworm, Eisenia foetida. The Journal of Cell Biology. 6: 61-66.

Harender, R., and Bhardwaj, M. L. 2001. Earthworms' role in soil biology. Chandigarh, India.

Haynes, R. J., Fraser, P. M., Tregurtha, R. J., and Piercy, J. E. 1999. Size and activity of the microbial biomass and N, S and P availability in earthworm casts derived from arable and pastoral soil and arable soil amended with plant residues. Pedobiologia. 43: 568-573.

Heredia, R. B., Dueñas, S., Castillo, L., Ventura, J. J., Briano, M. S., Del Rio, F. P., and Rodríguez, M. G. 2008. Autofluorescence as a tool to study mucus secretion in Eisenia foetida. Comparative Biochemistry and Physiology Part a: Molecular and Integrative Physiology. 151: 407-414.

Hirigoyenberry, F., Lassalle, F., and Lassegues, M. 1990. Antibacterial activity of Eisenia fetida andrei coelomic fluid: transcription and translation regulation of lysozyme and proteins evidenced after bacterial infestation. Comparative Biochemistry and physiology. B, Comparative Biochemistry. 95: 71-75.

Horst, R. 1883. New species of the genus Megascolex Templeton (Perichaeta Schmarda) in the collections of the Leyden Museum. Notes from the Leyden Museum. 5: 182-196.

Hossam, E. D., O.Mohamed. Z. Zedan, N.A . Ibraheim. El-Shimy. S. Rouwaida and Ali. 2012. Anti-inflammatory, antipyretic and antioxidant activities of the earthworms extract. J. Biol. Earth Sci. 2: 1.

Hrzenjak, M., Kobrehel, D., Levanat, S., Jurin, M., and Hrzenjak, T. 1993. Mitogenicity of the earthworm's (Eisenia foetida) insulin-like proteins. Comparative Biochemistry and physiology. B, Comparative Biochemistry. 104: 723-729.

Jairajpuri, M. S. 1993. Earthworms and vermiculture: an introduction. Earthworm resources and vermiculture. 1-5.

Jalal, F., 1998. Species diversity and abundance of earthworms in crop lands and orchards in Faisalabad district. M.Sc. Thesis, Department of Zoology and Fisheries, Agriculture University, Faisalabad.

Julka, J., M.1985. Oligochaeta: Himalayan ecosystem series: fauna of Western Himalaya, part 1: Uttar Pradesh. Zoology Survey. India. 17–22.

Julka, J. M. 1987. Earthworms (Oligochaeta: Annelida) of Orissa, India.

Julka, J. M. 1993. Earthworm resources and vermiculture. The Survey.

Julka, J. M. 1996. Annelid diversity in the Thar Desert. Faunal diversity in the Thar Desert: gaps in research. Scientific Publishers, Jodhpur. 71-76.

Julka, J. M., and Paliwal, R. 2005. Distribution of earthworms in different agro-climatic region of India. Soil Biodiversity, Ecological Processes and Landscape. Oxford and ABH Publications Co. Pvt. New Delhi. 3-13.

Julka, J., M. 1988. The fauna of Indian and the adjacent countries. Megadrile, Oligochaeta (Earthworm). Zoology Survey. Calcutta, India. 399.

Kale, R. D. 1998. Earthworm: Cinderella of organic farming. Prism.

Kale, R. D. 2005, January. Diversification in the field of earthworm research. In National seminar on vermicompost technology and waste management, Mangalore university, Mangalore, 28-29th June.

Kale, R. D., and Bano, K. 1991. Time and space relative population growth of Eudrilus eugeniae. Advances in management and conservation of soil fauna. Oxford IBH Publication, New Delhi. 657-664.

Khanum, H. 1999. Diversity and abundance of earthworm species in some cultivated and non-cultivated fields of Jaranwala. M.Sc. Thesis, Department of Zoology and Fisheries, Agriculture University, Faisalabad.

Khatoon, S. 1996. Habitat preference and abundance of earthworms in different crops of district Jhang. M.Sc. Thesis, Department of Zoology and Fisheries, Agriculture University, Faisalabad.

Kooch, Y., and Jalilvand, H. 2008. Earthworms as ecosystem engineers and the most important detritivors in forest soils. Pakistan Journal of Biological Sciences. 11: 819-825.

Lachnicht, S. L., and Hendrix, P. F. 2001. Interaction of the earthworm Diplocardia mississippiensis (Megascolecidae) with microbial and nutrient dynamics in a subtropical Spodosol. Soil Biology and Biochemistry. 33: 1411-1417.

Lalitha, R., Fathima, K., and Ismail, S. A. 2000. Impact of biopesticides and microbial fertilizers on productivity and growth of Abelmoschus esculentus. Vasundhara The Earth, 1(2), 4-9.

Lee, K. E. 1983. The influence of earthworms and termites on soil nitrogen cycling. In International colloquium of soil zoology. 8: 35-48.

Lee, K. E. 1985. Earthworms: their ecology and relationships with soils and land use. Academic Press Inc.

Lunt, H., A.and Jacobson, H. G. M. 1944. The chemical composition of earthworm casts. Soil Sciences. 58: 367–375.

Mackay, A. D., and Kladivko, E. J. 1985. Earthworms and rate of breakdown of soybean and maize residues in soil. Soil Biology and Biochemistry. 17: 851-857.

Mannan, M. A., Jahan, M. S., Ali, M. O., and Khan, A. R. 1994. Bioecology of earthworm, metaphire (Pheretima posthuma) raillant. Bengla. J. Zool. 22: 133-137.

Martin, A. 1991. Short-and long-term effects of the endogeic earthworm Millsonia anomala (Omodeo)(Megascolecidae, Oligochaeta) of tropical savannas, on soil organic matter. Biology and Fertility of Soils. 11: 234-238.

Matausic-Pisl, M. I. R. J. A. N. A., Tomicic, M., Micek, V. E. D. R. A. N., and Grdisa, M. I. R. A. 2011. Influences of earthworm extract G-90 on haematological and haemostatic parameters in Wistar rats. Eur Rev Med Pharmacol Sci. 15: 71-78.

Mihara, H., Ikeda, R., and Yonnet, T. 1996. The useful of earthworm powder. Miyazaki Medical College, Kiyotake, Miyazaki.

Milochau, A., Lassègues, M., and Valembois, P. 1997. Purification, characterization and activities of two hemolytic and antibacterial proteins from coelomic fluid of the annelid Eisenia fetida andrei. Biochimica et Biophysica Acta (BBA)-Protein Structure and Molecular Enzymology. 1337: 123-132.

Monahan-Earley, R., Dvorak, A. M., and Aird, W. C. 2013. Evolutionary origins of the blood vascular system and endothelium. Journal of Thrombosis and Haemostasis. 11: 46-66.

Naheed, I., Ghafoor, A., and Qureshi, J. I. 2003. Biodiversity of earthworms in Gutwala and Thakriwala forests at Faisalabad, Pakistan. Pakistan journal of zoology. 35: 171-173.

Nainawat, R., and Nagendra, B. 2001. Density and distribution of earthworms in different localities of Jaipur. Journal of Eco-Physiology. 4: 9-13.

Nakajima, N., Mihara, H., and Sumi, H. 1993. Characterization of potent fibrinolytic enzymes in earthworm, Lumbricus rubellus. Bioscience, biotechnology, and biochemistry. 57: 1726-1730.

Nijhawan, S. D., and Kanwar, J. S. 1952. Physico-chemical properties of earthworm castings and their effect on the productivity of soil. Indian J Agric Sci. 22: 357-373.

Parkin, T. B., and Berry, E. C. 1994. Nitrogen transformations associated with earthworm casts. Soil Biology and Biochemistry. 26: 1233-1238.

Piearce, T. G., Oates, K., and Carruthers, W. J. 1990. A fossil earthworm embryo (Oligochaeta) from beneath a Late Bronze Age midden at Potterne, Wiltshire, UK. Journal of Zoology. 220: 537-542.

Popoviæ, M., Enjak, T. M. H., Babiæ, T., Kos, J., and Mira, G. A. 2001. Effect of earthworm (G-90) extract on formation and lysis of clots originated from venous blood of dogs with cardiopathies and with malignant tumors. Pathology Oncology Research. 7: 197-202.

Popović, M., Grdiša, M., and Hrženjak, T. M. 2005. Glycolipoprotein G-90 obtained from the earthworm Eisenia foetida exerts antibacterial activity. Veterinarski arhiv. 75: 119-128.

Prakash, M., and Gunasekaran, G. 2010. Gastroprotective effect of earthworm paste (Lampito mauritii, Kinberg) on experimental gastric ulcer in rats. Eur. Rev. Med. Pharmacol. Sci. 14: 171-176.

Rafiq, A., 2000. Morphometry, abundance, ecology of habitat and species association of earthworms along some water channels, water ditches, canals and rivers in agro ecosystem ofFaisalabad.M.Phil. thesis, Department of Zoology and Fisheries, Uniersity of Agriculture, Faisalabad.

Rafique, A., and Rana, S. A. 2001. Species association of some earthworms in the agroecosystem of Faisalabad and Sargodha. Pak. J Agri. Sci. 38: 3-4.

Rana, S. A., Rafique, A., and Qureshi, J. I. 2000. Ecological distribution of earthworm's species along some water channels, water ditches, canals and river in the Agro-Ecosystem of Faisalabad Division. Journal of Animal and Plant Sciences. 10: 126-130.

Sarwar, J. M., Sultana, S., Nasiruddin, P., and Monirruzzaman, S. 2005. Earthworm diversity, distribution and abundance in Gibandia districts of Bangladesh. In Proceedings of National Symposium-Environmental Crisis and Security in the New Millennium. Anmol Publications Pvt. Ltd., India. 23-35.

Scheu, S. 1987. The influence of earthworms (Lumbricidae) on the nitrogen dynamics in the soil litter system of a deciduous forest. Oecologia. 72: 197-201.

Scheu, S. 2003. Effects of earthworms on plant growth: patterns and perspectives: The 7th international symposium on earthworm ecology· Cardiff· Wales· 2002. Pedobiologia. 47: 846-856.

Scheu, S., and Parkinson, D. 1994. Effects of earthworms on nutrient dynamics, carbon turnover and microorganisms in soils from cool temperate forests of the Canadian Rocky Mountains—laboratory studies. Applied Soil Ecology. 1: 113-125.

Scheu, S., and Parkinson, D. 1994. Effects of invasion of an aspen forest (Canada) by Dendrobaena octaedra (Lumbricidae) on plant growth. Ecology. 75: 2348-2361.

Senapati, B. K., Mishra, B. K., Mishra, V., and Mishra, B. K. 1979. Earthworm distribution in pasture soils. Geobios. 6: 28-29.

Shen, Y. 2010. Earthworms in Traditional Chinese Medicine: (Oligochaeta: Lumbricidae, Megascolecidae). Zoology in the Middle East. 51: 171-173.

Shobha, S. V., and Kale, R. 2007. Antimicrobial potency of earthworm, Eudrilus eugeniae on certain plant pathogens.

Shuster, W. D., Subler, S., and McCoy, E. L. 2000. Foraging by deep-burrowing earthworms degrades surface soil structure of a fluventic Hapludoll in Ohio. Soil and Tillage Research. 54: 179-189.

Šimek, M., and Pill, V. 1989. The effect of earthworms (Lumbricidae) on nitrogenase activity in soil. Biology and fertility of soils. 7: 370-373.

Sinha, R. K., Herat, S., Agarwal, S., Asadi, R., and Carretero, E. 2002. Vermiculture and waste management: study of action of earthworms Elsinia foetida, Eudrilus euginae and Perionyx excavatus on biodegradation of some community wastes in India and Australia. Environmentalist. 22: 261-268.

Stein, E. A., Wojdani, A., and Cooper, E. L. 1982. Agglutinins in the earthworm Lumbricus terrestris: naturally occurring and induced. Developmental and Comparative Immunology. 6: 407-421.

Stephenson, J. 1921. Contributions to the Morphology, Classification, and Zoogeography of Indian Oligochæt. In Proceedings of the Zoological Society of London. 91: 103-141.

Stephenson, J. 1923. The Fauna of British India Including Ceylon and Burma: Published Under the Authority of the Secretary of State for India in Council. Oligochœta. Taylor and Francis.

Syers, J. K., Sharpley, A. N., and Keeney, D. R. 1979. Cycling of nitrogen by surface-casting earthworms in a pasture ecosystem. Soil Biology and Biochemistry. 11: 181-185.

Symondson, W. O. C., Glen, D. M., Erickson, M. L., Liddell, J. E., and Langdon, C. J. 2000. Do earthworms help to sustain the slug predator Pterostichus melanarius (Coleoptera: Carabidae) within crops? Investigations using monoclonal antibodies. Molecular Ecology. 9: 1279-1292.

Templeton, R. 1844. Descriptions of Indian Oligochaeta. Rec Indian Mus. 12: 89–91.

Tomlin, A. D., Shipitalo, M. J., Edwards, W. M., and Protz, R. 1995. Earthworms and their influence on soil structure and infiltration. Earthworm ecology and biogeography in North America. 33: 159-183.

Valembois, P., Roch, P., Lassegues, M., and Cassand, P. 1982. Antibacterial activity of the hemolytic system from the earthworm Eisenia fetida andrei. Journal of invertebrate pathology. 40: 21-27.

Wang, C., Sun, Z., Zheng, D., and Liu, X. 2011. Function of mucilaginous secretions in the antibacterial immunity system of Eisenia fetida. Pedobiologia. 54: S57-S62.

Wang, F., Wang, C., Li, M., Gui, L., Zhang, J., and Chang, W. 2003. Purification, characterization, and crystallization of a group of earthworm fibrinolytic enzymes from Eisenia fetida. Biotechnology Letters. 25: 1105-1109.