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Effect of abiotic factors on the distribution of earthworms in different land use patterns

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Abstract The distribution of earthworms is usually diverse and their numbers fluctuate in relation to the different abiotic factors and land use patterns of the soil. The aim of the present study is to determine the biodiversity, distribution and relative abundance of earthworms under different land use pattern and its relation to abiotic factors (physico-chemical properties) of the soil. Earthworms were collected from different sites on the basis of various environment niches like agriculture fields, gardens, nurseries, along the river and road side etc. by hand sorting method. Physico-chemical analysis of the soil was also done to know the important factors affecting earthworm biodiversity and distribution. Total five species of earthworms belonging to the families Megascolecidae and Octochaetidae were identified: *Metaphire posthuma*, *Lampito mauritti*, *Amynthas morissi*, *Eutyphoeus waltoni* and *Eutyphoeus incommodus*. *M. posthuma* was the most abundant species and found in all the collection sites while other four species were abundantly found in gardens and nurseries. Shannon–Wiener diversity index, Margalef species richness and Pielou's evenness was ranged from 0.11 to 0.37, 0 to 0.6 and 0 to 0.53 respectively. Principal component analysis also proved that the abiotic factors like pH, moisture, soil texture and OC has strong positive effect on the distribution of earthworm. Earthworm biodiversity and distribution have been found to be positively correlated with type of vegetation and moisture content at the different collection sites and also varied according to soil habitat, soil tillage and land used pattern.

Introduction

The fertility of soil depends on the biological diversity and soil faunal biomass. Earthworms (belonging to the Phylum Annelida, Order Oligochaeta, Class Clitellata) are known to be the most important soil fauna biomass in humid soils of temperate and tropical regions (Lee, 1985). The beneficial role of earthworms in the breakdown of dead plant material in the forest litter was first documented by Darwin (1881). For a long time, earthworms have been known as the farmer's friend, natural ploughmen, soil ecosystem engineers and intestines of earth. Earthworms can significantly influence soil physical, chemical and biological properties, hence improving the fertility and structure of soil (Doan et al., 2013; Singh et al., 2016). Earthworms also play an important role in mixing of mineral soils and plant materials. Various studies reported that the disturbance and degradation of natural forest affect the number of

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earthworms and their distribution (Baretta et al., 2007; Chandran et al., 2012). The distribution of earthworm is usually heterogeneous (Guild, 1952; Satchell, 1955; Svendsen, 1957) and their numbers fluctuate in relation to the abiotic factors of the soil (Evans and Guild, 1947). Environmental factors like moisture, temperature, pH and soil texture also affect the distribution of earthworms. Bhadauria and Ramakrishnan (1989) determined that regional earthworm biodiversity and species dispersal pattern was influenced by a variety of biotic and abiotic forces such as soil properties, surface litter inputs, surface vegetation type, dynamic land management history, local or regional climate and human pressure. The significance of diverse soil habitats is one of the most influencing factors affecting the overall earthworm distribution (Rajkhowa et al., 2014). Changes in land use patterns have also directly affected the composition and population structure of earthworm communities in different agro-climatic regions (Blanchart and Julka, 1997; Behera et al., 1999; Bhadauria et al., 2000; Lalthanzara et al. 2011). Endogeic earthworm appears a key feature of soil functioning in the urban context through their roles on organic matter transformation, the formation and maintenance of soil structure (Amosse et al., 2015).

There are about 1800 species of earthworm widely dispersed all over the world (Edwards and Bohlen, 1996) and constitute 80% of the total soil invertebrates biomass (Nainawate and Nagendra, 2001). In recent study, 3627 species are known worldwide (Kooch and Jalilvand, 2008). India is one of the important mega biodiversity countries and only 11.1% of earthworm diversity is available out of total global earthworm's diversity (Chaudhuri and Nath, 2011; Suthar, 2011). It includes about 408 species placed in 10 families and 69 genera (Dash, 2012). Michaelsen (1909) described the Indian Oligochaetes and produced taxonomic keys for all known species of earthworm in India. Stephenson (1923) and Gates (1972) documented the earlier work on earthworms in the Fauna of British India and compiled a monograph, which included species from Andaman and Nicobar Islands and North Eastern India while Julka (1988) further authenticated the work on Oligochaetes. Indian earthworm fauna is predominantly composed of native species, which constitute about 89% of total earthworm diversity in the country (Julka and Paliwal, 2005).

Despite varied habitat, good moisture content and intensive farming there have been fewer studies on earthworm diversity in the agro ecosystem of the northwestern part of Punjab. The present study is the first report to know the effect of different abiotic factors of soil on the distribution and relative abundance of earthworms collected from different habitat of this region.

Materials and methods

Study site

The study was conducted at different sites of northwestern part of Punjab, India (Fig. 1). Most of the northwestern part of Punjab lies in a fertile, alluvial plain with two rivers viz. Ravi and Beas. This area has an extensive irrigation canal system and is influenced by three seasons: summer, monsoon and winter. In summer (April to June) temperature typically rise as high as 43 °C, in monsoon season (July to September) a majority of rainfall occurs, and in winter (December to February) temperatures typically fall as low as 4 °C. There is a transitional period between winter and summer in March and early April, as well as a transitional season between monsoon season and winter in October and November. The average annual rainfall is 541.9 mm. Relative humidity generally exceeds 70% in the mornings except during the summer season when the humidity in the afternoon is about 25% or less. The available flora in northwestern part of Punjab is patches of grass, small bushes, and shrubs. Paddy, wheat, sugarcane and vegetables are the most important crops of this region during summer, winter and transitional periods.

Sampling and identification of earthworms

An extensive survey of the northwestern part of the Punjab was done in various environmental niches such as agricultural fields, irrigation channels, gardens, plant nurseries, urban ornamental gardens, waste and grasslands, kitchen gardens, canal sites and wastage drains. The characteristics of survey sites are shown in Table 1. Earthworms were sampled from 21 different sites for three consecutive seasons (Table 2). Earthworms were sampled by the hand-sorting method up to 30 cm deep using quadrats ($30 \times 30\ cm^2$ area) for each sampling site. A global positioning system (GPS) (Garmin, Gpsmap 78 s) was used to mark the latitude and longitude of each site. Moisture content was measured with a digital soil moisture meter (Micro make). The collected samples of earthworms with appropriate amount of soil were placed in polythene bags labeled with place name, date of collection, surrounding soil biota etc and brought to the lab for further study. Earthworms were washed in fresh water and sorted on the presence or absence of clitellum. Clitellated earthworms were narcotized in 70% ethyl alcohol and fixed in 5% formalin for 6–8 h and finally preserved in 5% formalin. The preserved samples were studied morphologically and dissected for study diagnostic taxonomic character such as spermathecae (number and location), prostate gland (location and shape), prostomium shape, and clitellum position.

Physico-chemical analysis of soil

Soil was taken from sites for its physico-chemical analysis. Soil was analyzed for texture, pH, electrical conductivity (EC), total dissolved salts (TDS), nitrogen (N), phosphorus (P), potassium (K), organic carbon (OC), ash, sodium (Na), calcium (Ca), lithium (Li) and heavy metals. Soil texture was measured using method of Bouyoucos (1962). EC, pH and TDS were measured using a digital meter (Eutech Instruments, PCSTestr 35 series). The method of Bremner and Mulvaney (1982) was used for estimation of Total Kjeldhal Nitrogen. Content of organic carbon and ash was measured by the method of Nelson and Sommers (1996). Phosphorus was estimated by the method of John (1970) using Systronics UV/Visible spectrophotometer-117. Sodium, potassium, calcium and lithium were analyzed by Systronics Flame Photometer-128.