ISSN: 2377-6196
The American Journal of
SCIENCE AND MEDICAL RESEARCH, 1(1), 120-128

Research Article Open Access

Effects of various soil management practice on earthworm population structure across rainy and post-rainy seasons under the maize crop

V. Srinivas Reddy[1], N. Venu[2] and M. Vikram Reddy[3]

[1-3] *Department of Zoology, Kakatiya University, Warangal-506 009, Telangana State, India*

*E-mail: *srinivasreddi1968@gmail.com*

Abstract

Background: Earthworms are known for their beneficial role in the soil system since the time immemorial. The present investigation was undertaken to assess the effects of various soil management practice on earthworm population structure, both number and biomass (wet), across rainy and postrainy seasons under the maize crop.
Methods: The earthworms were sampled by hand–sorting method in three randomly selected areas, each 25 x 25 cm, and 25 cm deep in each plot (replicate) every month during two crop seasons (July to September ,1996 and June to October, 1997) covering both rainy (June to September) and postrainy (October to January) seasons.
Results: The percentage composition of the juvenile earthworms ranged between 1.5 and 14.5 % across the treatments. In zero tillage treatments, their percentage composition ranged between 2.1 % in rice – straw amendment and 4.8% in farmyard manure amendment. In Shallow tillage treatments, its percentage composition ranged from 1.4 % in bare amendment to 2.3 % in farmyard manure amendment. In deep tillage treatments. In perennial ley treatments, they were in low density in pigeon pea treatment (92 m^{-2}) which increased to 133 m^{-2} in S. *hamata* treatment.
Conclusion: Analysis of Variance (ANOVA) revealed that the total earthworm population densities in tillage and organic amendment treatments were significantly different between rainy and post-rainy seasons, increasing more than fivefold during the postrainy season compared to that of the rainy season, the difference being statistically significant.

Keywords: Earthworm, Rainy and Post-rainy seasons, Maize crop, Biomass

INTRODUCTION

Earthworms are known for their beneficial role in the soil system since the time immemorial (Curry et al, 1992). They are beneficial to soil due to their influence on soil physic- chemical and biological properties such as porosity, aeration, and nutrient status and microbial biomass. Many authors have investigated the relationships between earthworms and soil fertility (Guild, 1952 ; Evans and Guild , 1948; Satchell, 1958, 1960, Edwards and Lofty, 1972, Lee, 1985, and Marinissen and Deruiter, 1993) and there is good evidence of earthworms improving soil aeration and water infiltration (Russell, 1973 ; Edwards and Lofty, 1977; Ehlers, 1975 ; Beaumer and Bakermans, 1973 ; Barnes and Ellis, 1979). They create macropores and tunnels by exerting pressure to push soil aside or by ingesting the soil and making tunnels (Dexter, 1991). These burrows and macrospores in the soil profile influence the aeration, infiltration and ease root penetration while the medium pores created by their casting influence the water holding capacity of the soil (Venu et al, 2015).

How to Cite this Article:
V. Srinivas Reddy, N. Venu and M. Vikram Reddy (2015). Effects of various soil management practice on earthworm population structure across rainy and post-rainy seasons under the maize crop. *The Ame J Sci & Med Res*, 1(1):120-128. doi:10.17812/ajsmr20151121.
Published online 21st June, 2015

Soils with earthworms drain from four to ten times faster than soils without earthworms (Guild, 1952). Their activity increased cumulative rainfall intake (Peterson and Dixon 1971). Cogle and Reddy 1994, Unpublished data). They have incrased the field capacity of some New Zealand soils by as much as 17 % compared with soils without their activity (Stockdill and Cossens, 1966). Similr results have been obtained in savannah in Nigeria, were cropping was shown to influence earthworm populations, which in turn affected infiltration rates (Wilkinson, 1975). Clearly, earthworms influence the drainage of water from soil and the moisture- holding capacity of soil, both of which are important factors for growing crops.

Barnes and Ellis (1979) investigated the effects of different methods of cultivation and direct drilling and disposal of straw–residues, on populations of earthworms. The effects of conservation tillage practices on the populations of earthworms in different types of agricultural ecosystems have also been investigated (Rovira et al, 1987). The effects of other soil management practices have also been reported. Teotia et al (1950) investigated the effects stubble mulching on number and activity of earthworms.

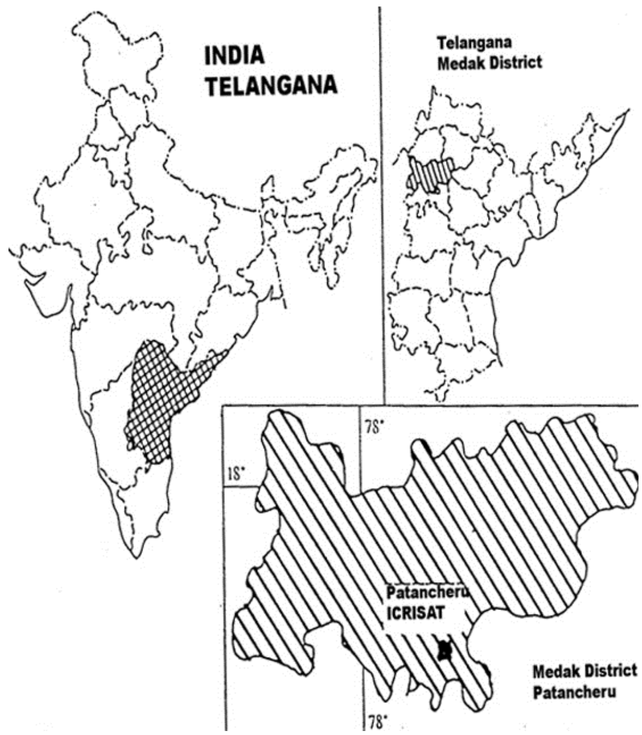
In semi–arid tropical arable soils, structural degradation through repeated cultivation is a major problem and the activity of beneficial soil organisms like earthworms may decrease due to such disturbance (Rovira et al, 1987; Stockdill et al, 1996; Rusel et al, 1973). However, very little information is available on the effects of such management practices on earthworm population densities in different tropical agroecosystems, particularly in India. Reddy and Reddy (1990) reported on the response of population structure and biomass of earthworms to conventional tillage in a semi–arid tropical grassland. Yule et al (1991) presented a preliminary report on the effects of soil management on population abundance and biomass of earthworms in a semi–arid tropical Alfisol. Tiwari (1993) investigated on the effects of different fertilizers including FYM on earthworm population densities. Therefore, the present investigation was undertaken to assess the effects of various soil management practice (the details of which are presented under study are and environmental conditions of this thesis) on earthworm population structure, both number and biomass (wet) , across rainy and postrainy seasons under the maize crop.

MATERIALS AND METHODS

Study Site:

The present experiment was established in July 1989, and carried out in the field designated RM19Bon the research farm at the ICRISAT Asia Center (Long : 78^0,17'^{0}'E,Lat.17^0 28'58'N", altitude Ca 547 m.s.I.), at Patancheru, 26 km northwest of Hyderabad, In Medak district of Telangana, India (Fig.1). The slope on the land surface is in the range of 1.5-2.0 %.

Figure-1. Map showing location of ICRISAT (Patancheru) in medak district, Telangana State, India



Soil type :

The soil of the study area belonged to the Patancheru series which is a member of the clayey-skeletal, mixed, Isohyperthermic family of Udic Rhodustalfs (Murthy et al., 1982). Analytical data of this soil type are given in El Stockdill et al (1987). The soil is locally regarded as a crusting, and profile hardening soil, The textural profile consisted of a sandy loam merging to sandy clay loam or light clay at 10-15 cm and then to gravelly sandy loam overlying murrum (parent material) rich in quartz gravel at depths ranging from 30 to 70 cm. It was formed on weathrered granite –gneiss.

Geomporphology and drainage :

Geomorphic study revealed that the area forms part of a peneplained surface of the ancient and stable Deccan Peninsula which had undergone several cycles of erosion, deposition and uplift. Sporadic monolithic domes and tors are also present. The general elevation ranges from 500 to 620 m above mean sea level (m.s.1). In the basaltic terrain in the south west of the area, the highest point is 620 m and the lowest is 580 m above m.s.1. and in the granite–gneiss terrain, the highest point is 610 m and the lowest is 500 m above m.s.1. Slope breake in the basaltic terrain occur at 10 to 15 m intervals.

The type area is characterised by dendritic and parallel to sub–parallel drainage systems of different densities. The streams are mostly seasonal and active during the rainy season. The northwestern part is drained by the Manjira river and the south – western part by the Musi river. The major portion drains into the Manjira river and its tributaries the Nakkavagu and the Palmavagu streams. The drainage system is most intricate in the east of the Type area where there are several small, seasonal tanks. The drainage pattern is similar in the north–west and tanks are fewer but larger.

Climate :

The climate of the area is semi-arid, characterized by mild-to-hot summers and mild winter. The weather of the present study area is generally dry except during the south-west monsoon season, extending from June to October, May is usually the hottest pre-monsoon month, with air temperatures of 42^0 to 43^0C. December is the coldest month with mean temperature around 20^0C. The mean annual air temperature is 25.9^0C. May is followed by stormy pre- monsoon cloud bursts in the early part of June. The regular monsoon rain occurs from the second half of June to the first week of October. The mean annual rainfall is 765.4 mm of which nearly 80 % falls during 4 months, extending from June to September. Intermittent dry spells occur occasionally during the rainy season. The pattern of rainfall is bimodal with two peaks, one in July and another in September, although there is considerable variation in rainfall from year to year.

The earthworms were sampled by hand–sorting method in three randomly selected areas, each 25 x 25 cm, and 25 cm deep in each plot (replicate) every month during two crop seasons (July to September ,1996 and June to October, 1997) covering both rainy (June to September) and postrainy (October to January) seasons. Thus, their populations were sampled eight times in total during 1996-1997. Each time, an iron grid of 25 cm2 was placed on a randomly selected area and cleared up the above–ground vegetation inside the frame and dug up to the depth of 25 cm in the morning (0600 to 0800 hrs). The earthworms were collected from each suck area, put in a polythene bag and brought to the laboratory. The adhering soil particles were washed off and they were soaked in filter paper to remove the water attached to their outer body wall and they were then enumerated. They were weighed (with gut content) for biomass (wet), narcotised with absolute ethanol, and sorted into various age groups such as adults (with clitellum) and juveniles (without clitellum and small worms). They were processed through 4 % formalin overnight, and preserved in 80 % ethanol. The adults were identified approximately, sent for more specific identification to an expert taxonomist at the Zoological survey of India.

Statistical Analysis:

Their population densities were converted m-2 across the 15 treatments. The data on the population densities of adult and juvenile earthworms and their biomass across the soil management treatments and seasons were analysed by ANOVA using GENSTAT.

RESULTS AND DISCUSSION

Qualitative Composition:

The earthworms sampled across the 15 soil management treatments such as different tillage and organic amendments with annual crop and the perennial ley treatments, belonged to two species–*Octochaetona phillotti* (Michaelsen) (Octochaetidae) and *Lampito mauritti* Kinberg (Megascolecidae)-the former being dominant. The mean percentage composition of the adults and juveniles of these two species of earthworms under the different soil management practices presented in Fig. 1 showed that the percentage composition of their adults ranged between <1 and 16.2 % across the treatments. In zero, shallow and deep tillage treatments, their percentage composition was low in bare amendments, ranging between <1 and 2.1 % and were slightly high ranging between 2 and 3.1 % in farmyard manure amendments, respectively. In perennial ley treatments, their percentage composition ranged between 8.1 % in pigeonpea treatment and 16.2 % in S. *hamata* treatment.

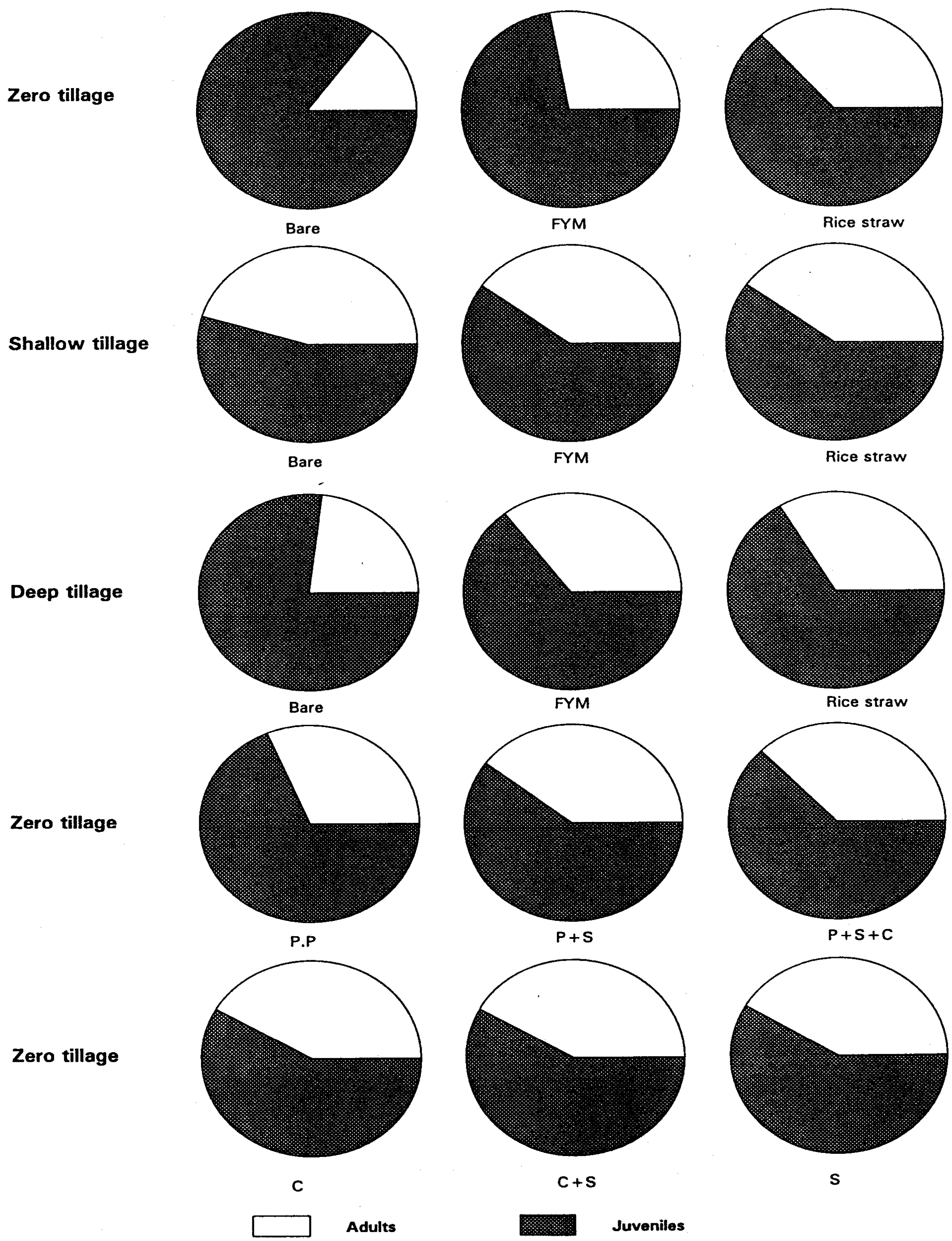
The percentage composition of the juvenile earthworms ranged between 1.5 and 14.5 % across the treatments. In zero tillage treatments. Their percentage composition ranged between 2.1 % in rice – straw amendment and 4.8% in farmyard manure amendment. In Shallow tillage treatments, its percentage composition ranged from 1.4% in bare amendment to 2.3 % in farmyard manure amendment. In deep tillage treatments. Its percentage composition ranged from 2 % in rice straw amendment to 2.4 % in bare amendment. In perennial ley treatments. Their percentage composition ranged between 11.1 % in pigeonpea treatment and 14.7 % in S. *hamata* treatment, as seen in adults.

The percentage composition of earthworm biomass (wet) across the treatments ranged between <1 and 20.7 %. In zero tillage treatments, it ranged from < 1 in bare amendment to 3.2 % in farmyard manure amendment. In shallow tillage treatments, it ranged between 1.4 % in rice–straw amendment and 2.1 % in bare amendment. In deep tillage treatments, it ranged between 1.2 % in rice–straw amendment and 1.5 % in bare amendment. In perennial ley treatments, it ranged from 9.3 % in pigeonpea + S. *hamata* +C. *ciliaris* treatment to 20.7 % in S. *hamata* treatment.

Temporal Variation:

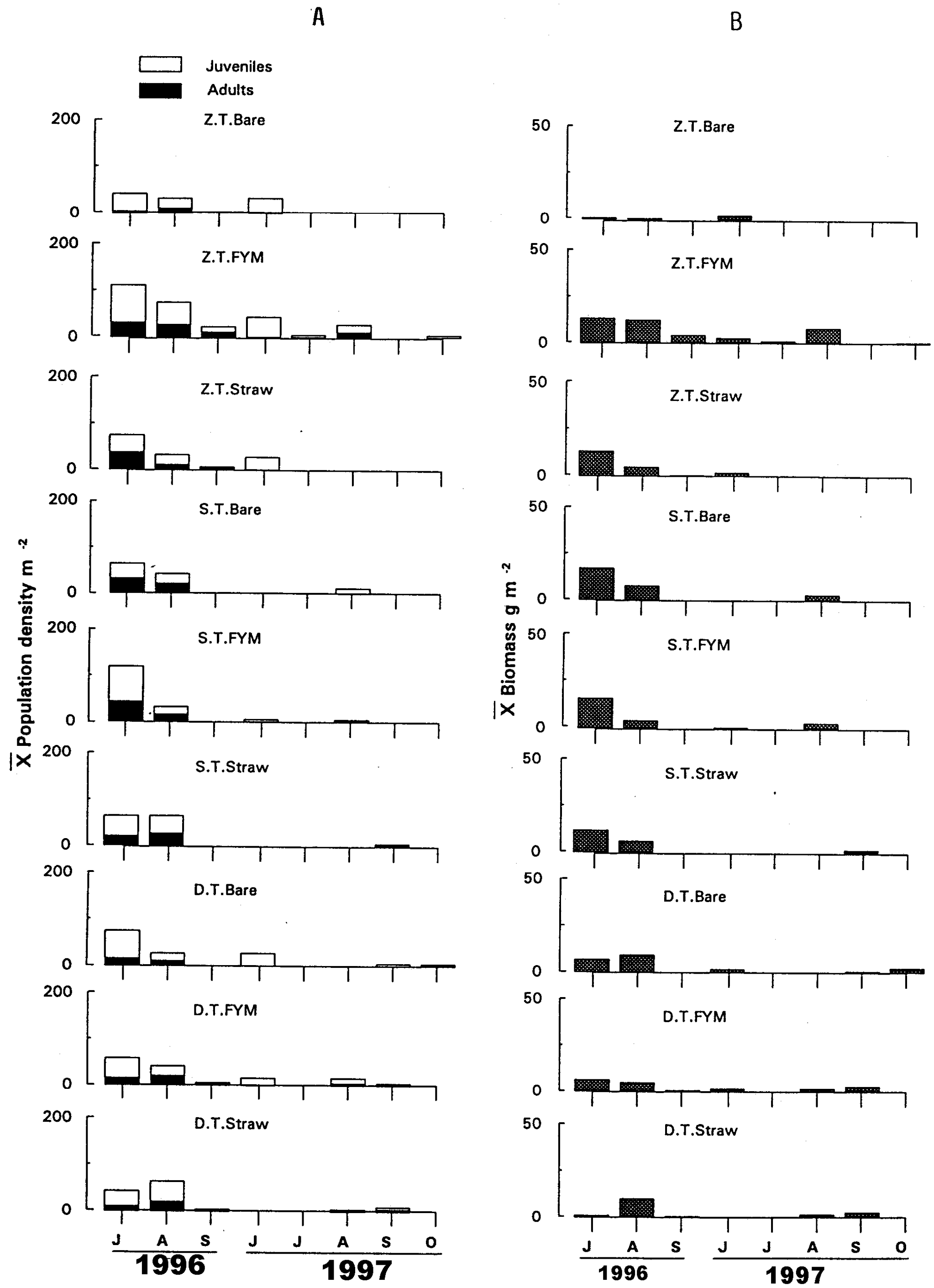
The seasonal fluctuation in the population densities of total earthworms across the 15 different soil management treatments presented in Figs. 2 and 3 revealed that the density was low (42 m^{-2}) in zero tillage bare and deep tillage rice–straw amendments and increased to nearly threefold in shallow tillage farmyard

Figure-2. Percentage composition of different age – groups of earthworms (adults and juveniles) across 15 soil management treatments.



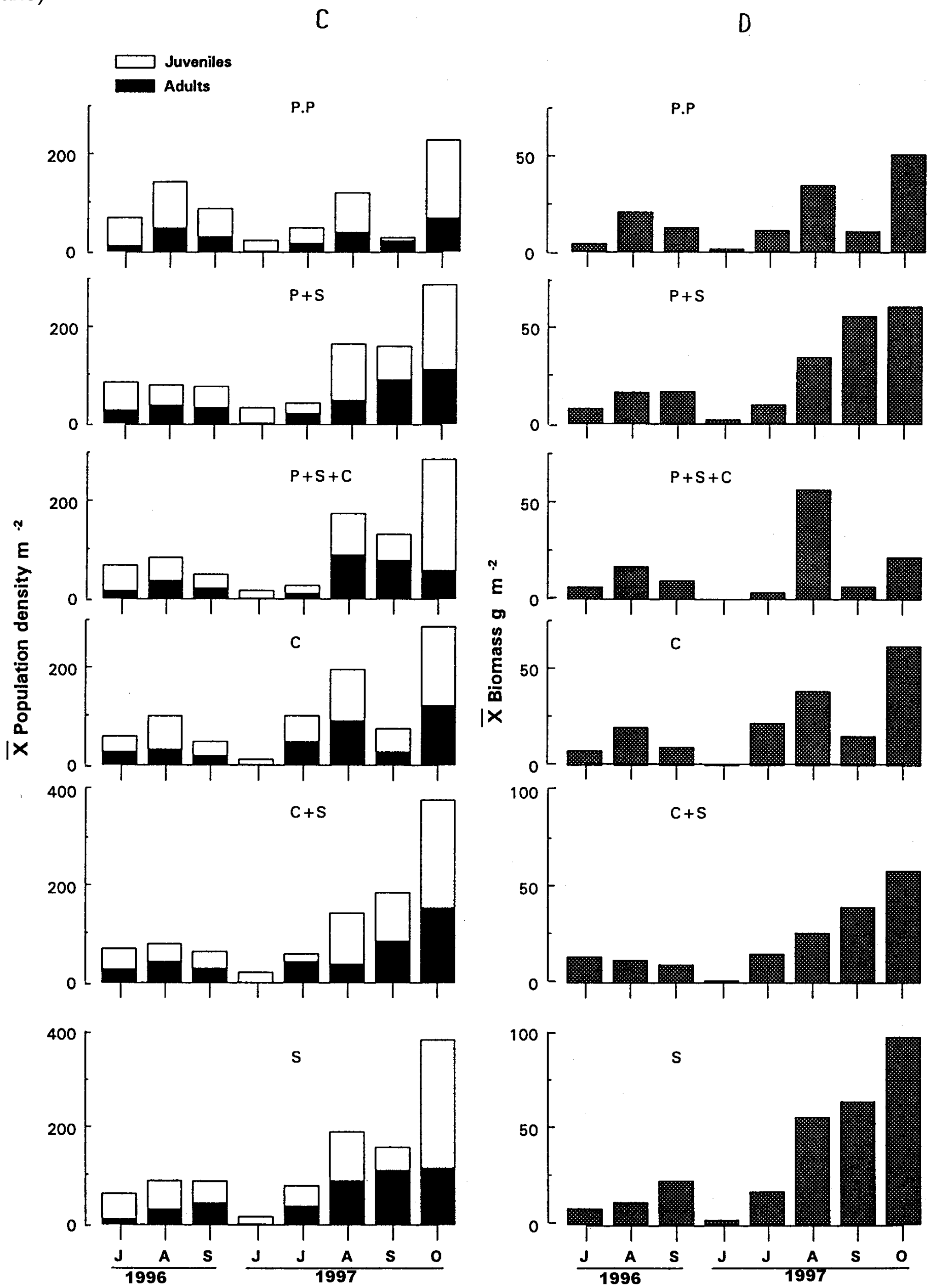
manure amendment (115^{m-2}), followed by that of zero tillage farmyard manure (110 m^{-2}) amendment, 10 days after sowing during the beginning of the rainy season (July, 1996). However, the density varied and was low (25 m^{-2})in deep tillage bare amendment and increased to more than fivefold in pigeon pea treatment (142 m^{-2}), 30 days after sowing during the middle of the rainy season (August, 1996) Sixty days after sowing, towards the end of the rainy season (September, 1996), it was low (3 m^{-2}) in zero tillage rice–straw amendment and increased to more than thirty fold in S. *hamata* treatment (90 m^{-2}), followed by that of pigeonpea treatment (87 m^{-2}). During the following fallow period, its density reduced to 5 m $^{-2}$ in shallow tillage farmyard manure amendment and increased more than eight fold in zero tillage farmyard manure amendment (42 m^{-2}), 210 days after harvesting the crop, when it was the beginning of the following rainy season (June,1997).

Figure-3. Seasonal fluctuation in the population densities of adult and juvenile earthworms m-2 (A) and that of biomass in g m-2 (B) across different tillage and organic amendment treatment (Z.T = Zero tillage, S.T.= Shallow tillage, D.T. = Deep tillage.).



During the second crop season, its density was low, 5 m^{-2} in zero tillage farmyard manure amendment and increased to more than twenty fold in C.*Ciliaris* treatment (101 m^{-2}) just a day after sowing, during the beginning of the rainy season (July, 1997) it was low, 5 m^{-2} in shallow tillage farmyard manure and deep tillage rice–straw amendments and increased to nearly forty fold in C. ciliaris treatment (196 m^{-2}), followed by S. *hamata* treatment (192 m^{-2}), 50 days after sowing during the middle of the rainy season (August, 1997). It was low (5-m^{-2}) in shallow tillage rice – straw, deep tillage bare and farmyard manure amendements and increased to more than thirty seven fold (186 m^{-2}) in C. *ciliaris* + S.*hamata* treatment, 75 days after sowing (September, 1997). It was low (5 m^{-2}) in zero tillage farmyard manure and deep tillage bare amendments, which increased to more

Figure-4. Seasonal fluctuation in the population densities of adult and juvenile earthworms m-2 (C) and that of biomass in g m-2 (D) under perennial ley crop treatments (P.P = *Pigeon pea*, S= *Stylosanthes hamata*, C = *Cenchrus ciliaris*).



than seventy–seven fold (384 m^{-2}) in S. *hamata* treatment, followed by that of C. *ciliaris* + S. *hamata* (380 m^{-2}) treatment, 90 days after sowing towards the end of the rainy season (October , 1997).

Analysis of Variance (ANOVA) revealed that the total earthworm population densities in tillage and organic amendment treatments were significantly different between rainy and post-rainy seasons, increasing more than fivefold during the postrainy season compared to that of the rainy season, the difference being statistically significant. Besides, their population densities showed significant variation across perennial ley treatments among the seasons. They were more than threefold higher during the postrainy season than that during the rainy season, the difference being statistically significant (Table-1).

Table-1. Response of population density (m^2) of total, adult and juvenile earthworms and their biomass (gm-2) to soil management treatment during 1996-1997.

Population density and biomass	Tillage and organic amendment treatments			Perennial ley treatments		
	Rainy	Postrainy	At 1% LSD	Rainy	Postrainy	At 1% LSD
Population density						
Total earthworms m^{-2}	40	229	35	134	452	82
Adult earthworms m^{-2}	13	96	21	58	160	34
Juvenile earthworms m^{-2}	24	136	22	73	306	56
Total biomass (g m^{-2})	8	34	6	21	65	9

Treatment Effect:

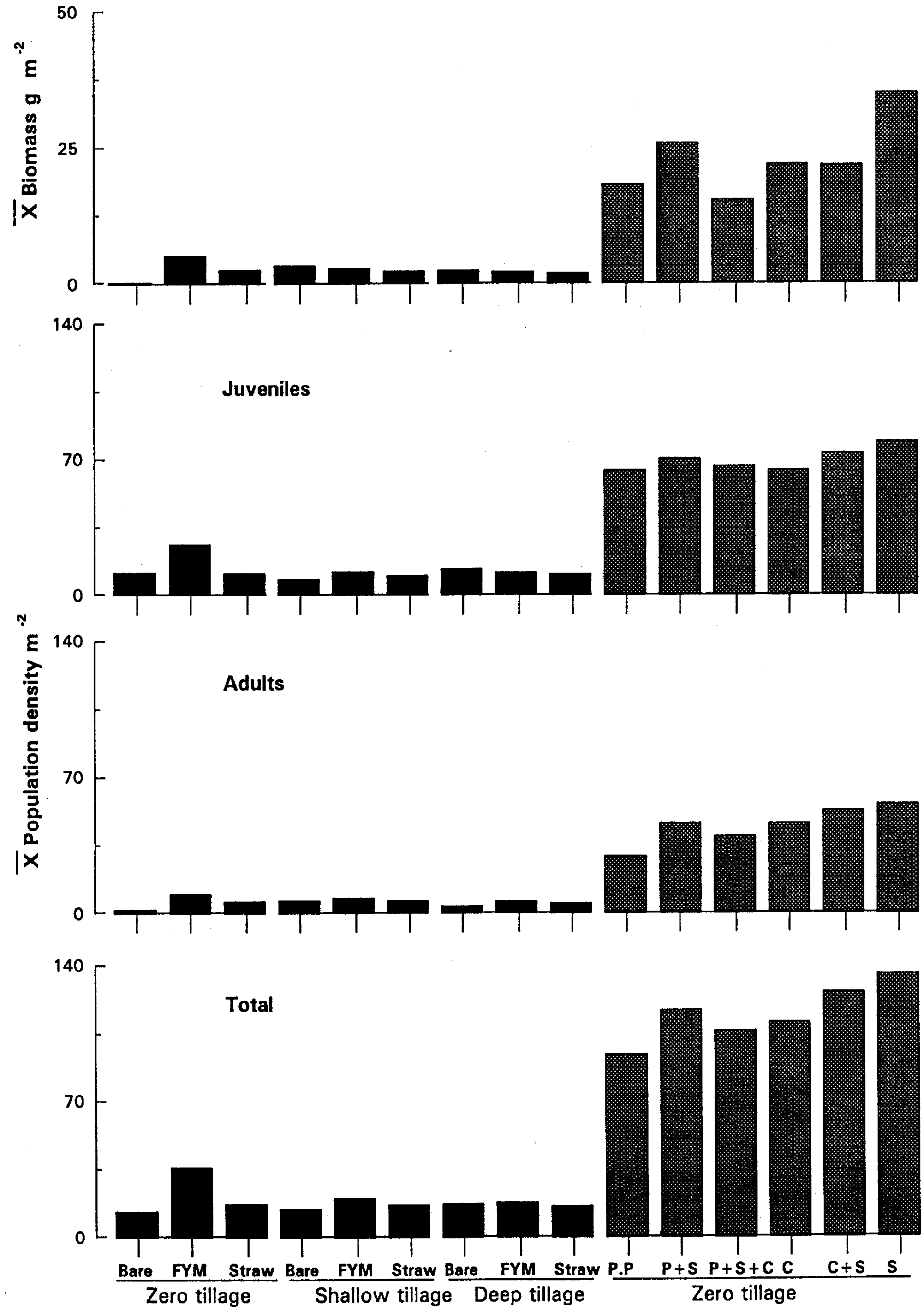
The population densities of total earthworms across the 15 soil management treatments presented in Fig. 4 revealed that the density was significantly low in the annual treatments (12 m^{-2}) compared to that in the perennial ley treatments (133 m^{-2}) ($P< 0.05$). Under annual crop, in zero tillage treatments, the density was low in the bare amendment (12 m^{-2}) which increased to more than two fold in farmyard manure amendment (35 m^{-2}). In shallow tillage treatments, there was not much variation between the organic amendments, as the densities ranged between 14 and 19 m^{-2}. In deep tillage treatments, the densities ranged between 15 and 17 m^{-2} across the organic amendments. In perennial ley treatments, they were in low density in pigeon pea treatment (92 m^{-2}) which increased to 133 m^{-2} in S. *hamata* treatment

The population densities of total earthworms significantly differed across the 15 treatments as revealed by the ANOVA, during the rainy season ($p< 0.05$) and the post rainy season ($P < 0.01$), the tillage and organic amendment and perennial ley treatments between the seasons (P. < 0.01). ANOVA of the monthly data showed that the population densities of total earthworms differed significantly across all the treatments during August 1996 ($P < 0.01$) , September 1996 ($P< 0.001$) and July, August , and September 1997 ($P < 0.01$) and October 1997 ($P < 0.05$), across both the tillage and organic amendments during September 1996 ($P< 0.05$), tillage during June 1997 ($P < 0.001$), organic amendment during August, 1997 ($P < 0.05$), and tillage and organic amendment interaction during August , 1997 ($P< 0.05$). Their densities also differed significantly across the perennial treatments during September 1996 ($P< 0.05$).

The number of species present in a community is a simple measure of biodiversity and is related to niche partitioning and sharing of resources among the species (Lee, 1985). There is little information on the effects of different soil management practices on species composition of earthworms which may be because of lack of long–term ecological investigations on these aspects. The number of species did not vary between the soil management treatments during the present study as only two species i.e., O.phillotti and L. mauritti were found across the treatments. Using Sorenson's quotient of similarity and Cole's coefficient of similarity, Phillipson et al (1976) showed two species association to be particularly frequent and concluded that the differences in soil characteristics including quantity and quality of organic matter and moisture regimes have direct effects on earthworm species associations. Gerard and Hay (1979) reported eight species of Lumbricide under polughing,tined cultivation, and direct drilling of a continuous barely ecosystem. House and Parmelee (1985) found two species of lumbricidae under no-tillage and conventional tillage practices. Parmelee et al (1990) recorded two species of Lumbricidae, two species of Acanthodrilidae, one species of Ocnerodrilidae in conventional and no-tillage agroecosystems. Mackay and Kladivko (1985) identified five species of Lumbricidae in soils receiving different tillage and cropping treatments. Two species of Lumbricidae and two species of Megascolecidae were recorded under four contrasting soil management practices in an andosol cropped system (Nakamura , 1988) Buckerfield (1992) found two species of Acanthodrilidae and one species of Lumbicidae in dryland cropping soils under conservation – tillage in South Australia. Two species of Lumbricidae and two species of Acanthodrilidae were found in Cereal and Lucerne production system (Baker, et al, 1993).

Earthworms were higher in number in the initial months of 1996 under annual crop with tillage treatments and the density was low during the remaining months of 1996 and 1997 in the tillage treatments. The reduction of earthworm population densities and biomass under tillage plots during June to October 1997 may be due to the deleterious effects of ploughing as well as carbofuran insecticide that was applied for shoot fly control. Most of the earthworms might have dies due to the effect of carbofuran (Parmelee et al, 1990). The plots cropped to maize consistently showed decrease of earthworms. Negligible numbers of juveniles and adults were subsequently found, indicating further toxic effects due to either residual carbofuran from 1996 or the small additional application of carbofuran again in July 1997. Parmelee et al (1990) reported that in the winter fall, carbofuran reduced the large annelid biomass and organic matter breakdown was inhibited in the no-till system. Raw (1962) , Mackay and Kladivko (1985), and

Figure-5. Population densities of adult, juvenile and total earthworms m-2 and their biomass in g m-2 across 15 soil management treatments (P.P = *Pigeon pea*, S = S*tylosanthes hamata*, C = *Cenchrus ciliaris*.)..



Hendrix et al (1987) reported that in the summer-spring , the no-till annelid biomass was significantly reduced and greater standing stocks of organic matter occurred after carbofuran application. According to Edwards (1980) and Lee (1985) many insecticides and fungicides are toxic to earthworms, the placement of the insecticides may affect earthworm mortality by affecting the proportion of the population exposed to the chemical.

It has been found that earthworm density and biomass was higher in perennial ley treatments with S. *hamata*. These treatments had generally more earthworms than the treatments which had less vegetational cover (pigeonpea). The treatments with perennial species either maintained or increased population and biomass compared to the annual treatments. These results are consistent with the findings of Evans and Guild (1948), Hopp and Hopkins (1946) and Barley (1959), who reported that the earthworm populations are higher under permanent pasture than under continuously cropped land, primarily because of the much greater supply of organic materials under pasture. Barely (1959), comparing earthworm populations in a 2- year pasture and permanent pasture, reported that the earthworm populations were higher in 2 years of pasture and in permanent pasture treatments than the tilled treatments. The marked difference in the numbers of earthworms was found under continuously cropped land compared to established pasture (Evans and Guild, 1948; Hopp and Hopkins, 1946; Barely 1961). This is attributed primarily to the difference in the total amount of decomposed plant residue available to earthworms as food; litter in the pasture may provide some abundant food source for the earthworms. Beside, the perennial ley crop treatments provided continuous favorable microclimate and unperturbed environment for the earthworms compared to the annual crop treatments.

Competing interests

The authors have declared that no competing interests exist.

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