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IMPACT OF TILLAGE AND SOIL MANAGEMENT ON POPULATION DENSITY AND BIOMASS OF A MEGASCALECID EARTHWORM *LAMPITO MAURITII*

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ABSTRACT
Agricultural practices can affect earthworms directly by the mechanical action of the tillage operation as well as indirectly as a result of the consequent change in the soil and environment. The effect of tillage practices on earthworm population used as an indicator of soil biological status, has been studied by comparing the population of a no-tilled area to that of a tilled area. A marked difference in population density, age structure and biomass of earthworms, between the tilled land and the no- tilled land has been observed. Results showed that maximum population density of the earthworm *Lampito mauritii* was 560 ± 28.09 worms m^{-3} in the no-tilled area, where as in the tilled area density was 540 ± 23.09 worms m^{-3}, with a difference in total worm density by 16%. In the no-tilled area immatures, matures and juveniles contributed 61.35, 24.9 and 13.75 percent respectively (on annual average basis) to the total population, where as in the tilled area percent contribution was 73.40, 13.54 and 13.06 of immatures, matures and juveniles respectively. The immature was 12.05% higher in the no-tilled plot to that of the tilled plot. The paper deals in detail with the impact of agricultural practices on the dominant earthworm species *(L. mauritii)* found in both grassland and cropland.

INTRODUCTION

Earthworm is one of the most important natural workhorses in the soil. The earthworm activities provide many beneficial aspects related to chemical and physical properties of the soil. Increased activities potentially favours increase in aeration, aggregate stability, water infiltration, mixing and decomposition of plants residue, availability of organic and inorganic nutrients, which directly or indirectly enhances the productivity of soil.

Earthworms are the dominant invertebrates in most soils world wide in terms of both biomass and activity (Edwards, 1998). The density and diversity of earthworms are mainly controlled by environmental factors that influence their biological cycles, such as temperature, moisture, organic carbon supply (Deibert, 1983; Chaudry and Mitra, 1983). In addition to this main crop and soil management practices , especially tillage, have a potentially negative effect on the earthworm populations by drying the soil, disturbing the worm holes, compacting the soil, providing rapid destruction to organic matter and removing protective cover essential for survival during the winter months (Lee, 1985). According to Lee, 1985 the gradual decline in earthworm abundance with successive tillage after the initial increase was due to subsequent adverse changes in soil environmental condition.

Review of literature reveals that lots of work has been done on earthworms in India. Earthworm population dynamics in relation to different soil types has been reported (Edwards and Lofty, 1972; Ghosh, 1993; Sarwar *et al.*, 2005; Sathianarayanan and Khan, 2006; Sinha *et al.*, 2007; Bansiwal and Rai, 2010). Influence of vegetation on population dynamics of earthworm also been studied (Low, 1972). Effetcs of pesticides on the earthworm has also been observed (Fransis and Knight, 1993). However there is no report on the effect of agricultural practices on the earthworm population in India a country whose economy is based on agriculture. To fill this lacuna, the present study was undertaken to have first hand information on impact of tillage practices during farming on earthworm.

MATERIALS AND METHODS

Our study was conducted from March 2008 to February 2009 at Ranchi. Both cultivated tilled plot (cropland) and a grassland site *i.e.* no-tilled plot were selected having no human and other interference than farming. The cultivated (tilled site) site is paddy *(Oriyaza sativa)* field and was under tillage practice. The grass land (non-tilled site) site is located just adjacent to the tillage site at the one end of landscape position.

Earthworms were sampled by monolith method and hand sorted once in a month following Dash and Patra (Dash and Patra, 1977). On the basis of length and clitellar development earthworms were divided into three age classes-juvenile (<2 cm. non clitellate), immature (≥ 2cm < 4cm non clitellate) matures (≥ 4cm clitellate). The population was expressed as number of individuals per cubic meter. Preservation and analysis of worms were made according to Dash and Patra, 1977; Senapati and Dash, 1980. Five replicates of freshly sampled worms were categorized into different size groups and weighed separately after being gut evacuated and were kept in oven at 85ºC for 24h to obtain dry weight. Gut evacuation of worms was done by keeping them half immersed

in distilled water (changed every 12h) in glass petridish for 24h.

RESULTS

Qualitative analysis of the worms showed three species in cropland (*L.mauritii, P. excavatus* and *O.occidentalis)* where as four species in the grassland (*L. mauritii, P. sansibaricus, P. bengalensis* and *D. willsi. L.mauritii)* was the common species in both the sites, therefore was selected to study the impact. In the no- tilled land the soil pH ranged from 5.81 ± 0.05 to 6.67 ± 0.11. Tempareture was highest in May 2008 where as lowest in December, 2008. The organic carbon content of soil ranged from 5.30 ± 0.09 mg C g^{-1} soil to 6.74 ± 0.27 mg C g^{-1} soil where as OMC ranged from 9.13 to 11.61.The N P K value ranged from 0.46 ± 0.02 to 0.54 ± 0.02, from 21.6 ± 0.68 to 29.1 ± 0.19, and from 142.8 ± 0.87 to 147.9 ± 0.33 mg g^{-1} soil in different months (Table 1). In the tilled plot soil pH ranged from 5.93 ± 0.09 to 6.58 ± 0.03, temperature was maximum in May and minimum in December 2008 respectively (Table 2). The organic carbon ranged from 5.48 ± 0.14 to 7.78 ± 0.40 mg C g^{-1} soil, whereas OMC from 9.44to 13.41 mg Cg^{-1} soil. The N P K of the soil ranged from 0.63 ± 0.01 to 0.83 ± 0.02, from 23.1 ± 0.29 to 30.5 ± 0.73 and from 142.9 ± 0.82 to 148 ± 0.82 mg g^{-1} soil.

The population density of *Lampito mauritii* in no-tilled plot i.e. grassland was maximum 560 ± 28.09 m^{-3} in August 2008 and minimum 35 ± 28.09m^{-3} in April 2008, with an average of 209.50m^{-3}. The density of juvenile, immature and mature worms ranged from 35 ± 10.05m^{-3} in October2008 to 160 ± 20.40m^{-3}in August 2008, from 35 ± 12.71m^{-3}April2008 to 300 ± 25.56m^{-3}in September 2008, from15 ± 10.01m^{-3} March 2008 to 190 ± 33.17m^{-3}in October 2008.The population was nil in the month of May 2008. The age structure of *L.mauritii* during the study period was found to be 13.75% of juveniles, 61.35% of immature and 24.09% of mature worms (Table 3). In the tilled plot *i.e.* cropland, the total population density of *L.mauritii* was maximum 540 ± 23.09 m^{-3} in September 2008 to 10 ± 10.01 m^{-3} in May 2008, with an average of 175.41 worms m^{-3}. The density of juvenile, immature and mature worms ranged from 25 ± 15.95m^{-3} in

Table 3: Seasonal population dynamics of different age group (density No.m^{-3}/month ± SEM) of *Lampito mauritii* in no-tilled area

Month	Age group Juvenile	Immature	Mature	Total
Mar-08		40 ± 10.05	15 ± 10.01	55 ± 12.45
Apr-08		35 ± 12.71		35 ± 12.71
May-08				0
Jun-08		45 ± 15.15		45 ± 15.15
Jul-08	70 ± 10.65	240 ± 19.07	45 ± 19.56	355 ± 21.98
Aug-08	160 ± 20.40	295 ± 22.16	105 ± 14.98	560 ± 28.09
Sep-08	80 ± 11.16	300 ± 25.56	165 ± 13.95	545 ± 25.12
Oct-08	35 ± 10.05	245 ± 21.19	190 ± 33.17	470 ± 18.86
Nov-08		140 ± 18.98	85 ± 22.36	225 ± 14.76
Dec-08		55 ± 13.05	20 ± 11.05	75 ± 13.05
Jan-09		75 ± 24.64		75 ± 24.64
Feb-09		70 ± 20.98		70 ± 20.98
Total	345	1540	625	2510
Av.	86.25	140	89.28	209.16
% Con.	13.75	61.35	24.9	

Av. = Average; Con. = Contribution

Table 1: Average monthly values of edaphic parameters in no-tilled area

Month	pH	Soil temp (ºC)	Organic carbon (mg C g^{-1} Soil)	OMC (mg g^{-1} soil)	Nitrogen (mg N g^{-1} soil)	Phosphorus (kg P $hec.^{-1}$)	Potassium (kg K $hec.^{-1}$)
Mar'08	5.81 ± 0.05	25.25	5.30 ± 0.09	9.13	0.50 ± 0.01	22.6 ± 0.46	143.8 ± 0.87
Apr'08	6.20 ± 0.03	27.6	5.42 ± 0.03	9.34	0.48 ± 0.01	21.6 ± 0.68	142.2 ± 0.52
May'08	6.67 ± 0.27	29	5.65 ± 0.12	9.74	0.46 ± 0.01	29.3 ± 0.38	144.5 ± 1.09
Jun'08	6.37 ± 0.14	28.4	6.49 ± 0.09	11.18	0.50 ± 0.11	28.9 ± 0.20	146.5 ± 0.89
Jul'08	6.41 ± 0.10	28.2	6.74 ± 0.27	11.61	0.47 ± 0.01	28.3 ± 0.13	145.4 ± 0.44
Aug'08	6.17 ± 0.14	24.6	6.72 ± 0.06	11.58	0.48 ± 0.0.2	27.4 ± 0.20	146.7 ± 0.60
Sep'08	6.67 ± 0.11	24.25	6.45 ± 0.05	11.11	0.54 ± 0.02	27.3 ± 0.14	147.0 ± 0.20
Oct'08	6.53 ± 0.11	25	6.60 ± 0.11	11.37	0.54 ± 0.02	29.1 ± 0.19	147.6 ± 0.36
Nov'08	6.18 ± 0.15	22.14	6.65 ± 0.26	10.77	0.54 ± 0.03	28.5 ± 0.16	147.9 ± 0.33
Dec'08	6.12 ± 0.10	19.43	5.70 ± 0.09	11.46	0.50 ± 0.03	24.9 ± 0.15	147.5 ± 0.44
Jan'09	6.03 ± 0.18	19.8	5.76 ± 0.20	9.82	0.46 ± 0.02	27.3 ± 0.17	145.7 ± 0.37
Feb'09	6.28 ± 0.19	20.41	5.80 ± 0.30	9.93	0.48 ± 0.01	26.3 ± 0.12	145.8 ± 0.35

Table 2: Average monthly values of edaphic parameters in tilled area

Month	pH	Soil temp (ºC)	Organic carbon (mg C g^{-1} soil)	OMC (mg g^{-1} soil)	Nitrogen (mg N g^{-1} soil)	Phosphorus (Kg P $hec.^{-1}$ soil)	Potassium (Kg K $hec.^{-1}$ soil)
Mar'08	6.29 ± 0.05	25.3	7.43 ± 0.04	12.8	0.64 ± 0.02	23.6 ± 0.46	145.3 ± 0.56
Apr'08	5.93 ± 0.09	27.5	5.99 ± 0.06	10.32	0.64 ± 0.02	23.1 ± 0.29	142.9 ± 0.82
May'08	6.33 ± 0.06	28.9	5.48 ± 0.14	9.44	0.67 ± 0.03	27.9 ± 1.06	144.0 ± 0.49
Jun'08	6.40 ± 0.03	28.4	7.43 ± 0.04	12.8	0.71 ± 0.01	29.8 ± 1.01	147.8 ± 0.60
Jul'08	6.05 ± 0.06	24.3	8.22 ± 0.05	14.17	0.81 ± 0.02	29.5 ± 0.31	144.5 ± 0.40
Aug'08	6.34 ± 0.03	24.2	7.62 ± 0.23	13.13	0.81 ± 0.01	28.4 ± 0.98	146.3 ± 0.83
Sep'08	6.58 ± 0.03	24.25	7.72 ± 0.29	13.3	0.83 ± 0.02	29.7 ± 0.87	148.8 ± 0.54
Oct'08	6.53 ± 0.11	25.0	7.78 ± 0.40	13.41	0.76 ± 0.11	28.1 ± 0.70	148.9 ± 0.79
Nov'08	6.46 ± 0.05	22.5	6.74 ± 0.33	41.61	0.65 ± 0.01	30.5 ± 0.73	147.7 ± 0.78
Dec'08	6.12 ± 0.10	19.3	5.96 ± 0.16	10.27	0.63 ± 0.01	27.7 ± 0.69	147.2 ± 0.29
Jan'09	6.21 ± 0.02	19.2	5.96 ± 0.16	10.22	0.61 ± 0.01	29.1 ± 0.57	147.9 ± 0.29
Feb'09	6.19 ± 0.02	20.32	5.93 ± 0.24	11.15	0.61 ± 0.01	27.6 ± 0.89	145.6 ± 0.54

October 2008 to 145 ± 20.40m^{-3} in August 2008, from 10 ± 10.10m^{-3}in May 2008 to 360 ± 22.16m^{-3} in August2008, from 05 ± 11.06m^{-3}in July2008 to 105 ± 22.31m^{-3} in October2008. The age structure of *L.mauritii* was found to be 13.06% of juveniles, 73.04% of immature and 13.54% of mature worms in cropland (Table 4).

Table 4: Seasonal population dynamics of different age group (density No.m^{-3}/month ± SEM) of *Lampito mauritii* in tilled area

Month	Age group Juvenile	Total Immature	Mature	
Mar-08		35 ± 10.05		35 ± 10.05
Apr-08		30 ± 12.71	0	30 ± 12.71
May-08		10 ± 10.01	0	10 ± 10.01
Jun-08		40 ± 15.15	0	40 ± 15.15
Jul-08	60 ± 10.15	320 ± 19.07	5 ± 11.06	385 ± 25.17
Aug-08	145 ± 20.40	360 ± 22.16	35 ± 19.23	540 ± 23.09
Sep-08	45 ± 11.16	245 ± 25.56	80 ± 16.87	370 ± 22.01
Oct-08	25 ± 15.95	200 ± 21.19	105 ± 22.31	330 ± 23.61
Nov-08		120 ± 18.98	45 ± 11.05	165 ± 16.16
Dec-08		50 ± 13.05	15 ± 10.16	65 ± 21.59
Jan-09		70 ± 24.64	0	70 ± 24.64
Feb-09		65 ± 28.08	0	65 ± 28.08
Total	275	1545	285	2105
Av.	68.75	128.75	25.90	175.41
% Con.	13.06	73.4	13.54	

Av. = Average; Con. = Contribution

Table 5: Seasonal biomass dynamics of different age group (biomass g.dry wt. m^{-3}/month ± SEM) of *Lampito mauritii* in no-tilled area

Month	Age group Juvenile	Immature	Mature	Total
Mar-08		2.04 ± 0.16	1.12 ± 0.13	3.16 ± 0.21
Apr-08		1.92 ± 0.27		1.92 ± 0.27
May-08				
Jun-08		2.47 ± 0.12		2.47 ± 0.12
Jul-08	0.47 ± 0.04	13.92 ± 1.15	3.37 ± 0.61	17.76 ± 2.03
Aug-08	1.27 ± 0.15	17.4 ± 1.26	7.87 ± 1.17	26.54 ± 3.54
Sep-08	0.45 ± 0.06	13.39 ± 1.98	12.21 ± 2.14	26.05 ± 2.95
Oct-08	0.24 ± 0.02	13.06 ± 0.83	12.92 ± 2.78	26.22 ± 2.34
Nov-08		8.54 ± 0.28	4.67 ± 1.01	13.21 ± 1.23
Dec-08		3.24 ± 0.16	1.6 ± 0.20	4.84 ± 0.16
Jan-09		4.57 ± 0.31		4.57 ± 0.31
Feb-09		3.31 ± 0.33		3.31 ± 0.33
Total	2.43	83.86	43.76	130.05
Av.	0.6075	7.62	6.25	11.82
% Con.	1.87	64.48	33.65	

Av. = Average; Con. = Contribution

In grassland the total worm biomass was found to be 130.05g dry wt and the size (mean weight) of adult worm was .077g dry wt m^{-3}/worm. The total worm biomass was minimum 1.92 ± 0.27g dry wt. m^{-3} in April 2008, where as maximum 26.54 ± 3.54g dry wt. m^{-2} in the month of August 2008. The biomass of juvenile, immature and mature ranged from 0.24 ± 0.02 to 1.27 ± 0.15g dry wt. m^{-3} inOctober and August 2008, 1.92 ± 0.27g dry wt.m^{-3}in April2008 to 17.40 ± 1.26g dry wt.m^{-3}in August 2008, from 1.12 ± 0.13 to 12.92 ± 1.16g dry wt.m^{-3}in the month of March and October 2008 respectively. The percent contribution of juveniles, immature and matures was found to be 1.87%, 64.48% and 33.65% (Table 5). In the tilled plot (cropland) the total worms biomass was found to be minimum 0.48 ± 0.12 g dry wt. m^{-3} in the month of May 2008 and maximum 21.37 ± 1.76g drywt. m^{-3} in the month of August 2008. The size (mean weight) of adult earthworm was found to be 0.060g. dry wt. /worm. The juveniles contribute 2.03% with a minimum of 0.22 ± 0.04g dry wt.m^{-3} in October 2008 to 1.07 ± 0.18g dry wt.m^{-3} in August2008. The immatures were 77.94%, which was minimum 0.48g dry wt. m^{-2} in May 2008 and maximum17.64 ± 1.83g dry wt. m^{-3} in the month of August 2008. 20.03% of the total biomass were matures out of which 0.15 ± 0.05g dry wt. m^{-3} minimum was in the month of July2008 and 7.471 ± 1.16g dry wt. m^{-3} maximum in the month of October 2008 (Table 6).

Table 6: Seasonal biomass dynamics of different age group (biomass g.dry wt. m^{-3}/month ± SEM) of *Lampito mauritii* in tilled area

Month	Age group Juvenile	Total Immature	Mature	
Mar-08		1.67 ± 0.16		1.67 ± 0.16
Apr-08		1.77 ± 0.45		1.77 ± 0.45
May-08		0.48 ± 0.12		0.48 ± 0.12
Jun-08		2.16 ± 0.43		2.16 ± 0.43
Jul-08	0.42 ± 0.03	14.4 ± 0.88	0.15 ± 5.00	14.97 ± 1.02
Aug-08	1.07 ± 0.18	17.64 ± 1.83	2.66 ± 0.36	21.37 ± 1.76
Sep-08	0.38 ± 0.09	12.91 ± 1.71	5.56 ± 0.78	18.85 ± 2.02
Oct-08	0.22 ± 0.04	11.98 ± 0.76	7.71 ± 1.16	19.91 ± 1.45
Nov-08		7.1 ± 0.61	3.37 ± 0.55	10.47 ± 0.76
Dec-08		3.02 ± 0.34	1.2 ± 21.00	4.22 ± 0.87
Jan-09		4.21 ± 0.21		4.21 ± 0.21
Feb-09		2.99 ± 0.44		2.99 ± 0.44
Total	2.09	80.33	20.65	103.07
Av.	0.5225	6.69	3.44	8.58
% Con.	2.03	77.94	20.03	

Av. = Average; Con. = Contribution

DISCUSSION

Comparison of the population density and biomass of *L.mauritii* in two different habitats under different soil management practices is an important aspect to study the impact of this practice and also to make generalization. In both the habitats, the climatic conditions are the same while the edaphic conditions differed significantly. The difference in population density, biomass as well as change in the age structure can be attributed to the impact of managemental practices. Low (1972; Wyss and Glasstetter, 2002) reported that earthworm population in fields in England which has been tilled for 3 and 25 years respectively, were 50 and 15% of those found in old grassland. In the current findings also the worm density of grassland (no tilled site) is found to be 16% higher than that of the cropland (tilled site), when the cropland is being tilled for more than twenty years while grassland has no human interferenceapart from occasional grazing.

Adverse effect of tillage on earthworms are well documented in different countries (Karlen *et al.,* 1994; Kotcon, 2008). Population is shifted towards younger age groups and lower biomass as an impact of tillage or agricultural practices (Karlen *et al.,* 1994). Our findings also exhibit the same trend. Although the population density is higher by 16% in the grassland the percentage of immature is higher in the tilled plot by 9.20%. The size and mean weight of adult earthworms is also greater by about 25% in the tilled plot to that of the no-tilled plot. A decline in worms population has been reported in mid-summer as a direct result of spring tillage operations (Wyss and Glasstetter, 2002). These losses were equalized during the

following months (Gerard and Hay, 1979). But in India summer is dry so at the onset of rainy season, when tillage starts there is a drastic change in population density as well as composition of age group affecting the biomass, size and mean weight of the adult worm. Immediately after tillage *i*.e. in July the difference in the contribution of matures in tilled to that of the no-tilled plot is 22.7%. This difference gradually decreases in the following months and at the onset of winter it is as low as 2.01%. The higher number of adults in tilled area might be due to regeneration of the cut worms during tillage. The worms show capability to regenerate in both anterior and posterior direction and thereby survive even after cutting during tillage.

It can be concluded that managemental practices especially tillage has an adverse effect on the worm population. Previous studies have found that greater the intensity and frequency of tillage lower the population density of earthworms (Yahyabadi and Ardheshir, 2010). More researches are needed to understand the ecology of different species, their interactions and their potential role in promoting more sustainable farming system.

REFERENCES

Bansiwal, K. and Rai, N. 2010. Ultra structural changes in clitellum region of *E. Foietida* after treatment with malathion. *The Bioscan*. **5(2):** 207-210.

Chaudry, D. K. and Mitra, K.1983. Fluctuations in earthworm populations in different soil conditions. *Geobios*. **10:** 55-59.

Dash and Patra, 1977. Density, biomass and energy budget of tropical earthworm population from a grassland site in Orissa, India. *Rev. Ecol. Biol. Sol.* **14(3):** 461 -471.

Deibert, E. J. 1983. The role of soil physical properties in managing reduced tillage systems. *North Dacota Farm Research*. **41(4):** 30-33.

Edwards, C. A. (Ed.) 1998. Earthworm Ecology.CRC Press, Boca Raton, Florida. p. 389.

Edwards, C. A. and Lofty, J. R. (Eds.) 1972. *Biology of Earthworms*. Chapman and Hall, London, U.K. pp. 152 -158.

Fransis, G. S., Knight, T. L. 1993. Long-term effects of conventional and no-tillage on selected soil soil properties and crop yields in New Zealand. *Soil Till. Res.* **26:**193-210.

Gerard, B.M. and Hay, F. K. M. 1979. The effect on earthworms of ploughing, tined cultivation,direct drilling and nitrogen in a barley monoculture system. *J. Agric. Sci*. **93:** 147-155.

Ghosh, A. H. 1993. *Earthworm Resourses and Vermiculture,* Zoology Survey of India, Kolkata. pp. 14-19

Karlem, D. L. , Wollenhaupt, N. C., Erbach, D. C., Berry, E. C., Swan, J. S., Eash, N. S. and Jord ahl, J. L. 1994. Long-term tillage effects on soil quality. *Soil Till. Res*. **32:** 313-327.

Kotcon, J. B. 2008.16th IFOAM Organic World Congress, Modena, Italy. pp. 149-152.

Lee, K. E. 1985. Earthworms: Their ecology and relationships with soils and land use, Academic Press, Sydney, p. 441.

Low, A. J. 1972. The effecet of cultivation on the structure and other physical characteristic of grassland and arable soils (1945-1970). *J. Soil Sci*. **23:** 363-380.

Sarwar, Jahan Md., Sultana, S., Nasiruddin, P. and Monirruzzaman, S. 2005. Earthworm diversity, distribution and abundance in gibandia districts of Bangladesh proceedings of national symposium environmental crisis and security in the new millennium. pp. 23-25.

Sathianarayanan, A. and Khan, A. B. 2006. Diversity distribution aid abundance of earthworms in Pondicherry region. *Tropical Ecology*. **47(1):** 139-144.

Senapati and Dash. 1980. Effect of formalin preservation on the weight of the tropical earthworms. *Rev. Ecol. Biol. Soil*. **17(3):** 371-377.

Sinha, M. P., Gupta, D. K., Singh, A. and Kumari, M. 2007. Influence of vegetational coveron population dynamics and biomass of a megascolocid earthworm *L. pusillus*. *The Biosca*n**. 2(2):**113-119.

Wyss, E. and Glasstetter, M. 2002. Tillage treatmentsand earthworm distribution in a swiss experimental corn field. Direct Science-*Soil Biology and Biochemistry*.

Yahyabadi Mojtaba and Ardheshir, A. 2010. 19th World Congress of Soil Science, Soil Solution for a Changing World, Brisbane, Australia. pp. 19-21.