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Original Research

Sci Vis 10 (4), 159-167
October-December, 2010
ISSN (print) 0975-6175
ISSN (online) 2229-6026

Effect of fertilizer (NPK) on earthworm population in the agroforestry system of Mizoram, India

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Received 18 December 2010 | Accepted 31 January 2011

ABSTRACT

The effect of inorganic fertilizer (NPK) on earthworm population was studied for two years (2002-2004) under different plantations at Sakawrtuichhun (SKT) and Pachhunga University College (PUC) agroforestry sites in Mizoram, north-eastern state of India. Five species of earthworms, viz. *Drawida* sp., *Metaphire houletti* (Perrier), *Perionyx excavatus* (Perrier), *Perionyx macintoshi* (Stephenson) and *Eutyphoeus mizoramensis* (Julka et al.) under three families were identified in the study sites. Detailed study was carried out under different soil strata and on different age group of earthworms in plantations like maize+*Leucena leucocephala* (ML) and pine apple+citrus+*Leucena leucocephala* (PCL). Doses of inorganic fertilizer treatment were given as per state agriculture department recommendation. Earthworms were collected from five random sampling sites at monthly intervals by hand sorting method in each replicate. The most versatile species was found to be *Drawida* species. An epigeic species, *P. excavatus* showed significant population variation between NPK treatment and control in both study sites. The one-way ANOVA showed positive impacts of NPK fertilizer treatment on earthworm population. Four species of earthworms excluding the anecic *E. mizoramensis* showed a significant variation between the two treatments in PCL plantations of PUC. The uppermost stratum (0-10 cm) seemed to be the most affected by fertilizer treatment among the three strata. The Juvenile and immature worms were found to be most influenced by NPK application. The impact of NPK application on earthworm population was greater in PCL plantation compared to ML plantation.

Key words: NPK fertilizer; earthworm; agroforestry; population; density; plantation.

INTRODUCTION

Increased use of inorganic fertilizers to boost the agricultural productivity is a common practice in various parts of the world. It is reported that the use of inorganic fertilizer influences the population density and biomass of earthworms. Both beneficial[1-6] and harmful effects[7-11] of inorganic fertilizers on earthworm populations have been reported from different agroecosystems. The positive effect is probably an indirect effect of the increased

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crop biomass production and consequent increases in organic residues.[4] On the other hand ammonia and ammonia-based fertilizers can adversely affect earthworm populations. The harmful effect of inorganic fertilizers has been reported to be due to its strong acidic and toxic effect of ammonia on earthworms.[7-9,11] Sahu *et al.*[12] reported the effect of fertilizers on earthworm structure and dynamics in cane sugar field from India, indicating about 30 per cent decrease in worm population and decrease in the reproductive rate of earthworm. Similarly, Ma *et al.* recorded a drastic decrease in earthworm populations and biomass in grassland soils treated only with nitrogenous fertilizers.[13] However, farmers report increased numbers in the long run due to higher yields and more food for earthworms to feed upon.[14]

Despite considerable literatures available on the effect of fertilizers on earthworms elsewhere, no information is available on the effects of fertilizers on earthworm population in the hilly agroforestry system of Mizoram, India. The only available literatures on earthworm studies in Mizoram include the work of Julka[15] and Ramanujam *et al.*,[16] who had reported twelve species of earthworm from the state. Julka *et al.*[17] described new species of earthworm *Eutyphoeus mizoramensis* (Octochaetidae: Oligochaeta). No single paper on the effects of NPK fertilizer on earthworms has been published so far from Mizoram. The aim of the present investigation was to provide the possible effects of inorganic fertilizer on earthworm density, specific effect on different species and on different age groups under different soil strata in the agroforestry fields.

MATERIALS AND METHODS

Mizoram (21,081 sq. km.), located in north -eastern India lies between 21°56'N and 24°31'N latitude, 92°16'E and 93°26'E longitude. This hilly state (covered with tropical and subtropical forest) has three neighbouring states (Assam, Tripura and Manipur) and international borders with Bangladesh (west – 318 km) and Myanmar (east and south – 404 km). Annual rainfall is about 250 cm.

Two agroforestry based experimental plots were laid down. Experimental Site-I was set up near Sakawrtuichhun (SKT) village, northwest of Aizawl, at an elevation of 650 msl situated at 92°40'E and 23°45'N, and the slope varies from 40 to 65%. The soil is brown to dark brown in colour with clay to clay loam in texture. The land is left fallow for four years and grasses, like *Imperata cylindrica* L. and *Erianthus longisetosus* Anderss. ex Benth, are the dominant plant species before the area was taken up for agroforestry plantation. Experimental Site-II was situated within Pachhunga University College (PUC) campus, Aizawl, situated at 92°44'E and 23°43'N, at an elevation of 825 msl with the slope varies from 50 to 67%. The soil is brown in colour and sandy to clay loam in texture. It was previously dominated by a grass, *I. cylindrica*, and few trees like *Schima wallichii* (DC) Korth., *Albizia* sp., *Sapium baccatum* Roxb. The adjacent site is covered by semi-dense forest. Weeding was carried out manually in both sites when required using a hand hoe.

In both study sites the experimental field was divided into two big plots, one for PCL plantation and the other for ML plantation. Each of these plantations was further divided into two sub-plots. One of it was used as control and the other for NPK treatment. The plants introduced were a hedge - *Leucaena leucocephala* (Lamk) de Wit. (Hawaiian Giant), a horticultural plant - pine apple (*Ananas comosus* L.), tree species – citrus (*Citrus reticulata* Blanco), and a cereal crop - maize (*Zea mays* L.) in the following combinations:

Treatment 1: Pineapple + Citrus + *Leucaena leucocephala* (PCL-Control)
Treatment 2: Pineapple + Citrus + *Leucaena leucocephala* (PCL-NPK treated)
Treatment 3: Maize + *Leucaena leucocephala* (ML-Control)

Treatment 4: Maize + *Leucaena leucocephala* (ML-NPK treated)

Fertilizer was applied as per state government agriculture department recommendation as follows: PCL plantation: N, P, K (g/plant) in the ratio of 12.2:12.2:12.0 equivalent to urea – 16.1 g/plant, DAP (diammonium phosphate) - 26.5 g/plant and MOP (muriate of potash) - 20 g/plant, respectively. In ML plantation: N, P, K (Kg/ha) in the ratio of 60:40:40 equivalent to urea - 38.5 Kg/acre, DAP-34.7 Kg/acre and MOP–26.6 Kg/acre, respectively.

Earthworm sampling

Earthworms were collected from 5 random sites of 25 x 25 cm by 30 cm, at least 5 m apart at monthly intervals by hand sorting method following TSBF programme manual.[18] They were then fixed in 4% formalin for further studies. Strata-wise collection at three different depths, *viz*. 0-10 cm, 10-20 cm and 20-30 cm was recorded. Each earthworm specimen was counted as age-wise and species -wise. For age-wise counting, earthworms were classified in to three age-groups, *viz.* Juvenile (<2 mm), Immature (2 mm) but lacking spermathecae and adult for small sized species;[19] and for larger species Juveniles <4 cm, immature >4<8 cm and adults >8 cm length, Clitellate[20,21]. Density was determined as number of individuals per square meter. One-Way Analysis of Variance was employed to calculate the effect of inorganic fertilizer on earthworms by using SPSS version 7.5.

RESULTS AND DISCUSSION

A total of five species of earthworms have been recorded from the two treatments in both PCL and ML plantations. Four species of earthwormsm *viz*. *Drawida* sp., *Metaphire houletti, Perionyx excavatus* and *Eutyphoeus mizoramensis* belonging to three families were found in PCL plantations of both study sites. *P. macintoshi* was found in PUC control only. A single visit of *P. macintoshi* at PUC following heavy rain may be from its adjacent forest areas.

In PCL plantations, the density of earthworms ranged from 16 to 186 no. m^{-2} in control and 16 to 368 no. m^{-2} in NPK treated area of SKT (Figure 1). The density of earthworms ranged from 3.2 to 156.6 no. m^{-2} in control and 6.4 to 165.33 no. m^{-2} in NPK treated area of PUC (Figure 2). Whereas in ML plantations, the density ranged from 64 to 186 no. m^{-2} in control and 66 to 201 no. m^{-2} in NPK treated area of SKT (Figure 3) and that of PUC ranged from 32 to 67 no.m^{-2} in control and 42 to 75 no. m^{-2} in NPK treated area (Figure 4). Thus, in general, NPK fertilizer application showed a trend of increased population density of earthworm in both plantations of the two agroforestry sites. The positive effect of inorganic fertilizer (NPK) on earthworm density may be attributed to greater plant production soon after monsoon sets in which resulted in increased litter quantity,[3-5,22-24] and there are increased returns of organic material to the soil, in the form of decaying roots and herbage.[25] Bohlen[26] reported that most inorganic fertilizers favour the build up of large numbers of earthworms, probably due to the increased amounts of crop residues being returned to the soil.

In support of the present result, Mishra and Tripathy[27] concluded that earthworm population density, average length and biomass were enhanced by nitrogen fertilizer application. They also added that the earthworm secondary productivity increased from 8.8 to 13.9 g dry tissue m^{-2} after fertilizer application. The effects of mineral fertilizer on earthworm can be variable.[28] For instance Tiwari[2] reported that applications of inorganic NPK fertilizer caused significant increases in earthworm numbers, biomass, and casts. Similarly, Bohlen[26] is of the opinion that long-term application of inorganic fertilizers may adversely affect earthworm populations due to soil acidification or other changes in the soil

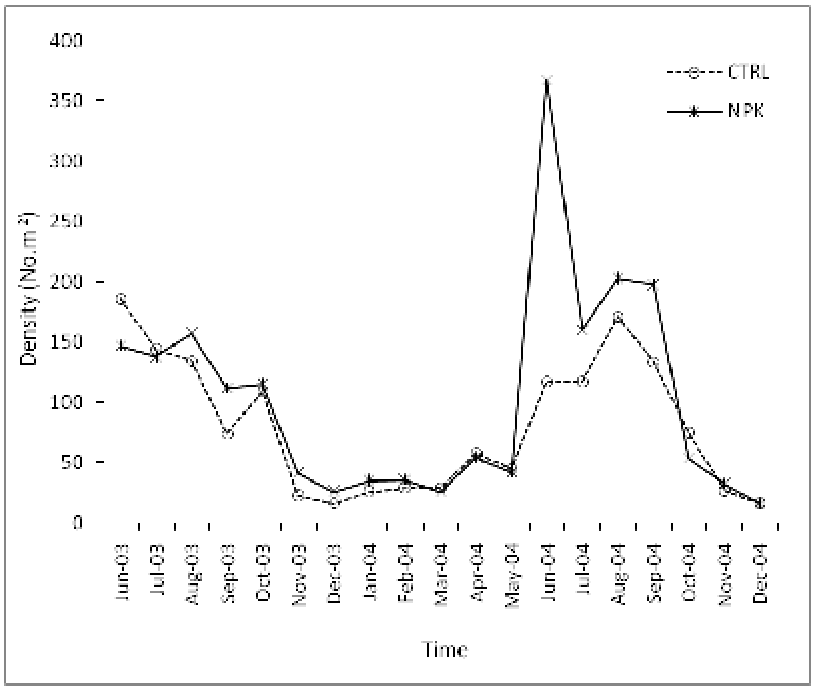

Figure 1. Effect of NPK in PCL plantation of SKT.

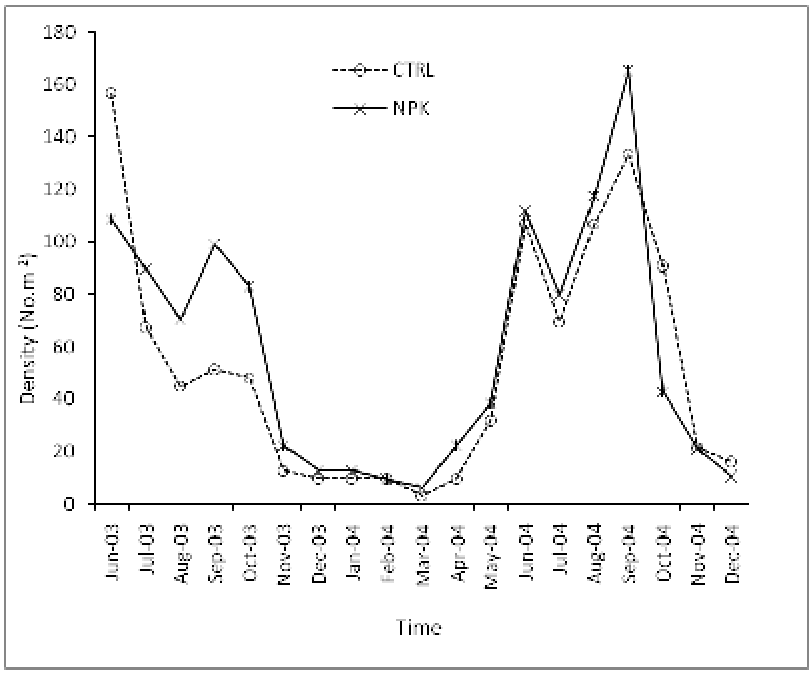

Figure 2. Effect of NPK in PCL plantation of PUC.

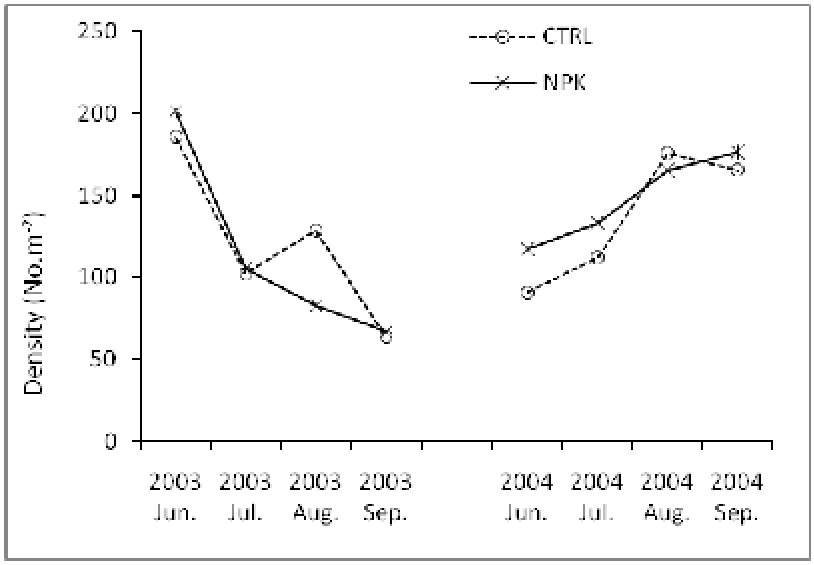

Figure 3. Effect of NPK in ML plantation of SKT.

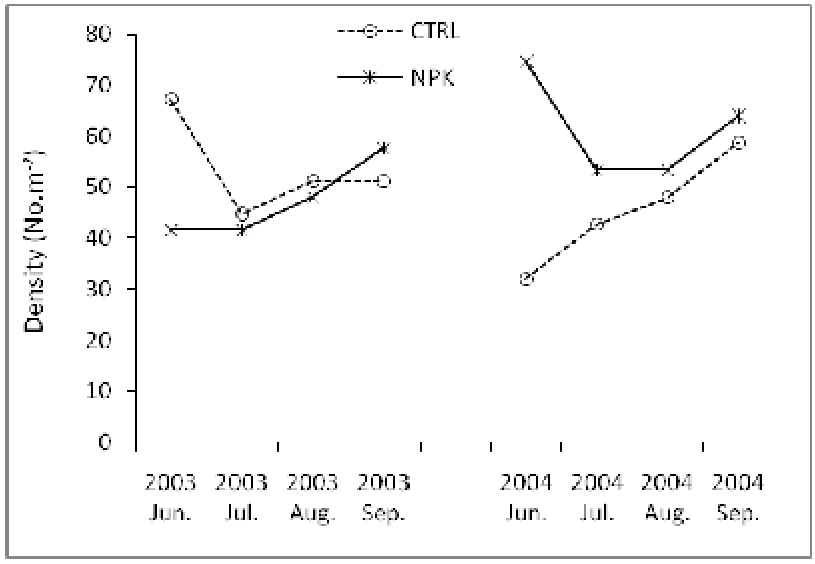

Figure 2. Effect of NPK in ML plantation of PUC.

environment.

The observations on response of NPK in different sites and plantations indicated the specific effect of inorganic fertilizers on earthworm population (Table 3). In PCL plantations, a significant variation (P≤0.01) between control and NPK treatment was observed in *P. excavatus* population at both SKT and PUC. These epigeic worms are favoured by increase plant litter and moisture which in turn is an affect of inorganic fertilizer. Similar observation was made by Ma *et al.*[13] who suggested that epigeic species show less reduction upon application on ammonium sulphate and sulphur-coated urea. They indicated that among the endogeic species, the effect of fertilizers varies from species to species. *M. houletti*, *Drawida* sp. and *P. macintoshi* showed a significant variation (P≤0.01) in PCL plantations between the two treatments at PUC only. Since *E. mizoramensis* living in deeper soil is not significantly affected immediately by NPK fertilizer application in PCL plantations but showed a decreasing trend in population density in ML plantations at SKT, this may be due to the feeding habits and micro-niche preferences. In line with this, Bugg[29] observed that fertilizer have specific effects on earthworms depending on the type of earthworm and fertilizer used. Ammonia and ammonia-based fertilizers can adversely affect earthworms.[9]

Table 1. One-Way ANOVA of different age group of earthworm with density in SKT.

Earthworm	Source of variation	0-10 cm	10-20 cm	20-30 cm
		F-ratio	F-ratio	F-ratio
Juvenile	CTRL x NPK (PCL)	12.937*	2.509	0
	CTRL x NPK (ML)	0.4	0.25	NA
Immature	CTRL x NPK (PCL)	1.005	5.841*	0.083
	CTRL x NPK (ML)	20.273	0	NA
Adult	CTRL X NPK (PCL)	23.621*	9.75**	0.692
	CTRL x NPK (ML)	0	0.000	NA

* and ** are significant at P≤0.05 and P≤0.01, respectively.

Table 2. One-Way ANOVA of different age group of earthworm with density in PUC.

Earthworm	Source of variation	0-10 cm	10-20 cm	20-30 cm
		F-ratio	F-ratio	F-ratio
Juvenile	CTRL x NPK (PCL)	39.977	11.492**	0
	CTRL x NPK (ML)	699.582*	0.25	NA
Immature	CTRL x NPK (PCL)	5.329*	1.114	18.519**
	CTRL x NPK (ML)	0.02	0.25	NA
Adult	CTRL X NPK (PCL)	90.278	1.663	4.167
	CTRL x NPK (ML)	2.776	0	NA

* and ** are significant at P≤0.05 and P≤0.01, respectively.

Table 3. One-Way ANOVA of earthworm species-wise effect of NPK treatment in PCL plantations.

Earthworm species	SKT	PUC
	F-ratio	F-ratio
Perionyx excavatus	25.679**	6.729**
Metaphire houletti	0	6.951**
Drawida sp.	6.993	615.718**
Eutyphoeus mizoramensis	0	0.913
Perionyx macintoshi	NA	41.149**

** are significant of P≤0.01

Table 4. One-Way ANOVA of earthworm species-wise effect of NPK treatment in ML plantations.

Earthworm species	SKT	PUC
	F-ratio	F-ratio
Perionyx excavatus	0	0.028
Metaphire houletti	5.390	0
Drawida sp.	0	26.570
Eutyphoeus mizoramensis	2.782	0
Perionyx macintoshi	NA	0

In ML plantation of SKT, there was no significant variation in juvenile population between Control and NPK treatment, whereas at PUC a significant variation (P<0.05) was observed at surface layer (0-10 cm) (Table 2). There was no significant variation in immature and adult populations in ML plantation of both the study sites in different soil strata (Table 1 & 2). This may be related to short duration of the maize plant resulting in a reduced surface cover. It might also be due to shorter duration of NPK treatment as it was applied for June to September only.

Although it was observed that the application of NPK fertilizer has no specific effect on a particular species in ML plantations (Table 4), but the PCL plantations of both study sites showed a significant effect of NPK fertilizer on earthworm species (Table 3). Thus the effect of inorganic fertilizer on earthworm species depends on the type of vegetation.

One-Way Analysis of variance (ANOVA) was employed to calculate the influence of inorganic fertilizer (NPK) on earthworm population (Table 1-4). The results of One-Way ANOVA (Table 1) in control and NPK treated area have shown a significant variation (P≤0.05) between juvenile populations of 0-10 cm depth in PCL plantation of SKT. A significant variation (P≤0.05) was observed in immature populations in PCL plantation of SKT between the controls and NPK treated at 10-20 cm depth may be related to the functional group of earthworms. Endogeic worms like *M. houletti* and *Drawida* sp. may pull the surface litter into subsurface obtaining sufficient amount of food supply. Adult worm shows more significant variations at 0-10 cm and 10-20 cm depth (P ≤ 0.05 and P ≤ 0.01, respectively). These significant variations in SKT provide evidence that inorganic chemical fertilizer influence earthworm population.

Unlike SKT, PUC shows a significant variation (P≤0.01) among juvenile population at 10-20 cm depth in PCL plantation, and the immature population shows variation at 0-10 cm and 20-30 cm depth by P≤0.05 and P≤0.01, respectively (Table 2). But, adult populations are not significantly affected by NPK application at all three soil strata. This may be attributed to the specific effect on younger groups of the earthworm population and the feeding habits of the dominant species. *Drawida* sp. is found to be most versatile throughout the year whereas all other species are available during the rainy season only. Khatnagar and Palta[30] reported that vertical distribution varies seasonally due to habitat preferences and feeding habits etc. There is a need for intensive investigation on the effects of fertilizer on different age groups of earthworm under different plantations in the tropical hilly agroforesry systems.

ACKNOWLEDGEMENT

This study was included within the Earthworm population ecological study project funded by the Indian Council of Agricultural Research (ICAR), New Delhi (Sanction No. F. No. 5(37) / 97 - SW & DF Dt. 9/1/2002). We thank to Dr. J.M. Julka, Consultant for earthworm identification and Vermiculture, Solan, H.P. (India) for identification of the specimens and the Principal, Pachhunga University College for providing laboratory facilities.

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