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Effects of five earthworm species on some physico-chemical properties of soil

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Abstract

An incubation experiment was conducted to study the changes that occur in organic carbon content, phosphorous and potassium availability and other soil properties with ingestion of soil mixed with rubber leaf litter and cow dung by five earthworm species *viz. Pontoscolex corethrurus*, *Drawida assamensis*, *Drawida papillifer papillifer*, *Eutyphoeus comillahnus* and *Metaphire houlleti* of rubber plantation in Tripura (India). Due to earthworm activity organic C (1.56-1.63%) and available P (14.71-27.60 mg 100 g^{-1}) and K (43.50-49.0 mg 100 g^{-1}) content of the soil increased significantly ($p<0.05$) in most of the earthworm species studied. *M. houlleti* and *D. papillifer papillifer* had the highest P (27.60 mg 100 g^{-1}) and K (49.0 mg 100 g^{-1}) mobilization capacity, respectively. Earthworms, irrespective of the species, increased the pH (7.05-7.17) and electrical conductivity (663-1383 μS cm^{-1}) of the soil significantly ($p<0.05$).

Key words

Rubber plantation, Soil, Physico-chemical properties, Earthworm cast

Introduction

Soil fertility depends on physical, chemical and biological attributes (Huerta *et al.*, 2007). Earthworms, as ecosystem engineers, play an important role in improvement of soil physical structure, organic matter dynamics and nutrient cycling rates through their peculiar feeding, burrowing and casting activities (Edwards and Bohlen, 1996). Sustained level of casting activities has been reported in the rubber plantations of Tripura (Chaudhuri *et al.*, 2009). Reports are available on the effects of earthworms on structure and physical properties of soil (Blanchart *et al.*, 1999; Brown *et al.*, 2004) but scantly on its chemical properties (Basker *et al.*, 1993). The study is important in order to know the role played by the earthworm species in nutrient cycling in the soil of rubber plantations with well canopy cover and deciduous litter fall (Chaudhuri *et al.*, 2008; Chaudhuri and Nath, 2011). Thus objectives of the present study were to analyze changes in the chemical (*viz*. pH, organic C, available P and K) and physical (electrical conductivity) properties of soil after it has been processed by five common earthworm species *viz. Pontoscolex corethrurus*, *Drawida assamensis*, *Drawida papillifer papillifer*, *Eutyphoeus comillahnus* and *Metaphire houlleti* of rubber plantation in Tripura.

Materials and Methods

Non-clitellate young geophagous earthworm species viz. *Pontoscolex corethrurus*, *Drawida assamensis*, *Eutyphoeus comillahnus* and epianecic earthworms like *Metaphire houlleti* and *Drawida papillifer papillifer* were collected from the soils of rubber plantation in Bishalgarh subdivision, West Tripura during August 2008 and acclimated under the laboratory conditions (temperature 32°C and humidity 85%). Cow dung and rubber leaf litter decomposed for 1 month and 6 months respectively, were collected, dried in hot air oven at 40°C for 7 days and ground to the particle size of <1 mm. Sieved and air dried soils of rubber plantation was mixed thoroughly with cow dung dust and rubber leaf litter (as feed additive) in 30:1:1 ratio (w/w) to prepare the incubation media for all the experimental and control pots. Rubber leaf litter had 52.68% C, 2.31% N, C/N ratio 22.75, 120.51 mg 100 g^{-1} P, 835 mg 100 g^{-1} K and 9.92% ash, respectively. Water was added to the food substrate to maintain 30% moisture.

Two earthworms of each species were introduced in each of the plastic pot (15´15´8 cm) containing 1600 g of substrate made up of soil with dung and litter mixture. About 40-50 small holes were made in the lids and sides of the culture pots for aeration. Three replicates were kept for each species. Control pots (three replicates) with the same substrate but without any earthworm, were also maintained. Both experimental and control pots were kept in B.O.D. incubator (REMI, India) at a temperature of 27°C for 90 days. In the experimental pots sign of earthworm activities as indicated by their burrowing and casting behavior were recorded. During the experimental period earthworm casts ejected were not removed from the pots and the incubation media were kept unchanged.

Following termination of the experiment, the earthworms were removed and the experimental and control soils were collected and air dried for seven days. Experimental (homogenized worm cast and incubated substrate) and control (incubated substrate without worm casts) soils were ground with mortar and pestle separately and sieved with 1 mm sieve. The soil samples were subjected to analysis of different physico-chemical properties. The pH was measured by ELICO pH meter (digital) using suspensions of the material in water in the ratio 1:2.5 (w:v). Total organic C was estimated by the rapid titration method of Walkley and Black (1934). Available P was determined by colorimetric method and K by flame photometric method (Jackson, 1973; Upadhyay and Sharma, 2001). Electrical conductivity was measured from 1:2 soil-water suspension (w/v) using conductivity meter. All chemical analyses were conducted in sets of quadruplicate (four subsamples derived from homogenized mixture of incubated substrates from sets of three pots – one for control and other for experimental). Significant differences ($p<0.05$) between control and experimental sets were determined by analysis of variance (ANOVA) and student's t-test.

Results and Discussion

Earthworm ingested organic materials together with inorganic soil particles, the proportions of which seemed to be species dependent. The ingested organic matter was macerated, mixed with inorganic soil particles, passed through the gut and excreted as a cast. In the experimental pots burrowing and casting activities were observed within 4 -7 days of earthworm inoculation. Burrowing activity was generally confined to areas near walls and bottom of the pots. Casts were usually found as coherent masses on the surface and also on the side walls of the pots and could not be easily separated from the soil.

Soil processed by earthworms irrespective of species showed significant increase ($p<0.05$) in soil pH making it neutral from acidic condition (Table 1). This confirms reports from other workers (Basker *et al.*, 1994). Earthworms neutralize the acidic soil as it passes through their guts by secretion of calcium carbonate from the calciferous glands or by excretion of ammonia into the intestine or by a combination of the both (Edwards and Bohlen, 1996).

Organic C content of the initial soil decreased significantly ($p<0.05$) in the control (without earthworm) as well as in the worm-worked soils of all the earthworm species studied following 90 days of experimentation. However, there was no significant difference ($p>0.05$) in organic C content among the soils without worms and those treated with geophagous species like *Drawida assamensis*, and *Eutyphoeus comillahnus* (Table 1). This indicates that the C assimilation efficiencies in these endogeic species are low and do not differ significantly among themselves. Significant increase ($p<0.05$) in organic C content in soils incubated with phytogeophagous earthworms like *Drawida papillifer papillifer* and *Metaphire houlleti* compared to the control was in part not only due to their preferential feeding of soil fractions enriched in organic compounds, but also because of addition of intestinal mucus (Edwards and Bohlen, 1996). Higher organic C content in the soils incubated with *Drawida papillifer papillifer* compared to control soil was also reported by Dkhar and Dkhar (2004). Significant increase in C content of the soil following its passage through the gut of *Metaphire*

Table - 1. Effects of different earthworm species on soil physico-chemical properties

Parameters	Soil with dung and litter mixture (0 days)	Soil with dung and litter mixture and without earthworms (90 days)	Soil with dung, litter mixture and earthworms (90 days)				
			P. corethrurus	*D. assamensis*	*D. p. papillifer*	*E. comillahnus*	*M. houlleti*
pH	6.56^a±0.03	6.96^b±0.02	7.17^c±0.01	7.14^c±0.01	7.15^c±0.02	7.05^d±0.02	7.17^c±0.02
OC (%)	1.77^a±0.03	1.50^b ± 0.05	1.56^{bc}±0.05	1.56^{bc}±0.05	1.63^{cd}±0.02	1.58^{bc}±0.01	1.61^{cd}±0.03
P (mg 100 g^{-1})	10.92^a±0.36	12.42^a±0.22	18.17^b±0.68	18.46^b±0.32	14.71^{ab}±0.84	23.96^c±4.33	27.60^c±0.98
K (mg 100 g^{-1})	41.33^a±0.44	41.50^a±0.29	45.00^b±0.87	45.00^b±0.87	49.00^c±1.00	43.50^{ab}±0.87	44.00^b±0.82
EC ($\mu S\ cm^{-1}$)	507^a±14.50	543^{ab}±34.80	1087^c±60.70	723^d±49.10	1383^e±109.3	703^{bd}±69.80	663^{ad}±5.93

Values are mean of three replicates ± SD. Values marked with different letters in the same row differ significantly at $p<0.05$. OC = Organic carbon, P = Available phosphorous, K = Available potassium, EC = Electrical conductivity *houlleti* and *Drawida papillifer papillifer* enhanced the stabilization of organic matter by accelerating its incorporation to organomineral complexes. In contrast, many workers (Chaudhuri *et al.*, 2000; Dominguez, 2004; Suther, 2007) reported significant decrease in organic C content in casts of litter feeding epigeic earthworms probably because of their higher carbon assimilating efficiencies.

Among the five earthworm species studied, except *Drawida papillifer papillifer*, all other species significantly increased ($p<0.05$) available P content of soil (Table 1). Rise in the level of available P content in worm-worked substrate is probably due to mineralization and mobilization of P by combined action of faecal phosphatase of earthworms and microbial activity in casts (Chaudhuri *et al.*, 2000; Vinotha *et al.*, 2000). In our present study, highest and lowest available P content of soils were noticed in presence of *Metaphire houlleti* and *Drawida papillifer papillifer*, respectively. Moreover, P availability in soils incubated with *Metaphire houlleti* and *Eutyphoeus comillahnus* were significantly higher ($p<0.05$) than those with *P. corethrurus*, *Drawida assamensis* and *Drawida papillifer papillifer*. It appeared that capacity of P mineralization in different earthworm species working in organic soil increased in the following order: *Drawida papillifer papillifer* < *Pontoscolex corethrurus* < *Drawida assamensis* < *Eutyphoeus comillahnus* < *Metaphire houlleti*. There are reports on dramatic increase in the available P content in worm-worked sewage sludge in presence of *Polypheretima elongata* and *Perionyx excavatus* (Chaudhuri *et al.*, 2001), and in the casts of *Metaphire houlleti*, *Eutyphoeus comillahnus* (Chaudhuri *et al.*, 2009) and *Pontoscolex corethrurus* (Sabrina *et al.*, 2009) compared to the surrounding soil. This indicates that P produced due to earthworm activity was the labile P in inorganic fractions (Ghosh *et al.*, 1999; Sabrina *et al.*, 2009).

Significant increase ($p<0.05$) in available K was observed in soils with *Pontoscolex corethrurus*, *Drawida assamensis*, *Drawida papillifer papillifer* and *Metaphire houlleti* (Table 1). Moreover, the soil processed by *Drawida papillifer papillifer* had significantly higher ($p<0.05$) available K content than the organic soils incubated with *Pontoscolex corethrurus*, *Drawida assamensis*, *Eutyphoeus comillahnus* and *Metaphire houlleti*. Similar report (Basker *et al.*, 1993) is available on temperate earthworm, *Lumbricus rubellus* which was more effective than *Aporrectodea caliginosa* in increasing the amount of available potassium. Elevated level of available K content in *Eutyphoeus gammiei* and *Polypheretima elongata* stabilized sewage sludge compared to earthworm-free sludge was reported by Chaudhuri *et al.* (2001). Recently significant increase ($p<0.05$) in available potassium in the casts of *Metaphire houlleti*, *Kanchuria* sp 1 and *Eutyphoeus gigas* of rubber plantation soil and *Pontoscolex corethrurus* of oil palm plantation have been documented (Chaudhuri *et al.*, 2009; Sabrina *et al.*, 2009). According to Edwards and Bohlen (1996), elevated levels of available potassium in earthworm casts are probably due to selective feeding by earthworms on materials enriched in this cation. In fact, gut transit increases mineralization converting phosphorous and potassium to forms available to plants (Edwards, 2004).

Electrical conductivity of the soils increased significantly ($p<0.05$) after 90 days of incubation in presence of earthworms irrespective of the species studied. Highest increase in electrical conductivity was recorded in soils incubated with phytogeophagous species *Drawida papillifer papillifer* (more than 2.5 times increase compared to the soils without earthworms). According to one recent report (Chaudhuri *et al.*, 2009), there was significant increase in electrical conductivity in the casts of *Pontoscolex corethrurus*, *Metaphire houlleti*, *Eutyphoeus comillahnus* and *Eutyphoeus gigas* compared to their surrounding soils of rubber plantation. Increase in the electrical conductivity of worm-worked soils in our present studies was probably due to the increase in the level of soluble salts (Chaudhuri *et al.,* 2009). Thus in presence of soil-dwelling earthworm species, acidic soil turns neutral, organic carbon generally becomes stabilized, nutrients available to plants (available P, K *etc.*) increase.

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