EFFECT OF SELECTED EARTHWORMS ON SOIL FERTILITY, PLANT GROWTH AND VERMICOMPOSTING

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ABSTRACT

The study investigates the effect of the endogenic earthworm Pontoscolex corathrurus on soil fertility and plant growth and three epigenic earthworms Perionyx excavatus, Eudrilus eugenia and Eisenia foetida on vermicomposting. At the organic farm site, year round abundance of P. corathrurus ranged from 4.95-19.6 for adults, 2-13.25 for juveniles and 2.2-7.3 for cocoons and in integrated farm site from 2.2-15.6 for adults, 1.5-11 for juveniles and 0.8-4.6 for cocoons. Effect of P. corathrurus activity on soil fertility relieved that worm casts are significantly high in N (9.7-6.5%) and C (5.7-3.5%) content than surrounding soil. The pH of casts was neutral compared to the fluctuating pH of surrounding soils, in both sites presence of P. corathrurus in pot experiments, significantly increased the growth of Zea maiz when inoculated with 7 earthworms per pot. Culturing of the 3 selected epigenic earthworms in 7 composting media, containing cow dung, vegetable refuse and rice straw in different ratios, showed that presence of cow dung significantly increased the multiplication rate. Vermicomposting yielded compost having higher N, P, Fe, and Mn levels, better particle size in comparison to the controls. Findings of the study confirm that earthworms commonly found in Sri Lanka can be easily used for soil fertility improvement and vermicomposting without having to import species from elsewhere.

Key words: Pontoscolex corathrurus, Perionyx excavatus, Eudrilus eugenia, Eisenia foetida, Epigenic, endogenic

INTRODUCTION

Earthworms (Annelida: Oligochaeta) contribute to soil fertility improvement, plant growth and play a key role in converting organic matter and composting garbage. There are about 3,627 species of terrestrial earthworms in the world (Reynolds 1994). Stephenson (1923) recorded 63 species of earthworms from Sri Lanka of which 47 were considered as zoo-geographically important to the Asian region. A recent study revealed 22 species of earthworms belonging to 16 genera and 9 families in 17 natural and agricultural sites in the Wet and Intermediate zones in Sri Lanka (Samaranayake 2008). These earthworms belong to three ecological categories, namely epigenic, endogenic and anecic based on morphological features, habits and location in soil (Bouche 1977). Of the endogenic species, Pontoscolex corathrurus showed the highest distribution in all the 17 sites. Adults, juveniles and cocoons and casts of P. corathrurus could be easily identified in the fields (Samaranayake 2008). According to Fragoso et al. (1996), P. corathrurus is an exotic species that originated in Central America and is now widely distributed all habitats in the tropics.

Earthworms play many different roles in soil. They play an active role in soil organic matter dynamics and nutrient turnover. A significant proportion of the ingested material assimilated by earthworms is secreted as intestinal cutaneous mucus with a greater C/N ratio than original resources (Lavelle et al. 1994). As a result, part of the N assimilated may be in excess and have to be excreted. Another reason for high mineral nitrogen excretion is the rapid turnover of N in earthworm biomass. Brossard et al. (1996) showed that the total P content was 43% higher in casts than in surrounding soil. Furthermore, conditions maintained in the gut of earthworms provide for microbial activity whereby considerable amounts of water and intestinal mucus are added to the worm casts which in turn enrich the soil. Earthworms facilitate dispersal of soil microorganisms by their feeding, burrowing and casting activity (Lavelle et al. 1994).

Results from laboratory experiments conducted over more than hundred years have indicated positive effects of earthworms on plant yield. Syers et al. (1984) have demonstrated that lumbricid earthworms from temperate regions are capable of stimulating plant growth in grasslands. Further, small scale experiments using non-lumbricid tropical geophagous earthworms have shown similar trends and indicated species- specific responses of plants to earthworm activity (Spain et al. 1992; Fragoso et al. 1996). Moreover, their findings showed that
optimum yield enhancement is achieved when the correct species of earthworms are inoculated. Also its population enhanced by management through producing components which can be utilized by the growing roots and also enhancing the release of nutrients in synchrony with the demands of the plants. Such long term field experiments were conducted in Peru, Ivory Coast and Mexico with the introduction of P. corathrurus which, greatly enhanced maize yields in most cropping cycles, when maize was grown off season with the addition of fertilizer (Lavelle et al. 1994).

The utilization of organic wastes through earthworms is called vermicomposting. It is a technical method of producing compost in an ecologically sound, economically viable and sociologically acceptable manner. Vermicompost can supply the full requirement of major nutrients for plant growth i.e. N, P, K; secondary nutrients i.e. Ca, Mg, S and also micro nutrients i.e. Cu, Zn, Mn and Fe. The average nutrient content of vermicompost is much higher than in the other types of compost (Singh 1996). Only other hand vermicompost is a rich source of vitamins and growth hormones like gibberellins which regulate plant growth. Fragoso et al. (1996) reported that single earthworm has to digest organic matter up to 5-30 times of its body weight per day in order to enhance the growth of beneficial soil bacteria which are the most divers and speediest agents for decomposing organic matter.

At present information on the role of local earthworm fauna in soil fertility improvement is scanty and inconclusive. In this study three interrelated objectives were investigated using the common endogenic earthworm, P. corathrurus, and three epigeic species Eudrilus eugenia, Eisenia fetida and Peryonix excavatus (Samaranayake 2008).

The specific objectives of the study were; 1. to confirm the year round occurrence of P. corathrurus (adults, juveniles and cocoons) in two differently managed agricultural sites; 2. to determine the pH, total C and N content in P. corathrurus casts in comparison to non ingested surrounding soil, in the two selected sites; 3. to determine the effect of P. corathrurus on growth of Zea maize in a pot experiment and; 4. to determine multiplication rate of three selected epigeic earthworm species in three composting media and the resulting nutritive level and particle size in comparison to controls.

**MATERIALS AND METHODS**

**Field sites**

For field studies two differently managed sites were selected; 1. an integrated farm site cultivated with winged beans at the In-Service Training Centre of the Department of Agriculture, Gannoruwa and 2. an organic farm site at Dekinda, Nawalapitiya. At each site, 20x20m plots were established to conduct the study.

**Survey of Pontoscolex corathrurus**

For the year round survey of P. corathrurus, 10 quadrates (25x25cm) were randomly placed in the filed plots. The surface casts found within the quadrates were collected and counted. Thereafter, soil was dug to a depth of 40cm in each quadrate, and placed in a tray. Soil was hand sorted and the number of cocoons, juveniles and adults of P. corathrurus in each quadrate was collected and recorded.

In this manner, ten soil samples were examined from each site at monthly intervals from July 1996 -1997. The rainfall data of these two sites were obtained from the climate database established and associated with DIVA GIS software.

**Chemical composition of P. corathrurus casts and surrounding soil**

Casts and soil collected on each sampling day were used for this experiment. Casts and soil were separately pooled. The pH of casts and soil was determined using the Piper method (Andreson and Ingram 1989). Total N content was determined using Kjeldhal method and total C using Walky Black method (Andreson and Ingram 1989).

**Effect of P. corathrurus on plant growth**

Effect of different numbers of P. corathrurus on the growth of Z. maize was determined in a pot experiments. The potting mixture consisted of 3 parts of soil (soil type RYP) and 1 part of cow dung (sterilized for 17h). This medium was put into clay pots (height 20cm, surface area 0.17m2) and inoculated with different numbers of adult P. corathrurus as indicated in Table 1. Each treatment was replicated 5 times. Two seeds of Z. maize (Variety “Ruwan”) were planted in each pot. Plant height, fresh and dry weight of roots and shoots of all plants were measured separately at 50d after seeding.

**Multiplication of earthworms for vermicomposting**

Multiplication of the 3 selected epigeic earthworms, E. eugenia, E. fetida and, P. excavatus in 7 different media were studied under laboratory condition. The 7 media used in the experiment were: (1) Cow dung, (2) Vegetable refuses, (3) Straw, (4) Cow dung + Vegetable refuse (1:1), (5) Cow dung + Straw (1:1), (6) Vegetable refuse + Straw (1:1) and (7) Cow dung + Vegetable refuse + Straw (1:1:1 ratio).
The total weight of each medium was 900g. Each medium was placed separately in plastic basins (30cm dia. and 15cm height). Each basin containing a specific medium was separately inoculated with 15 mature earthworms of each of the three species used in the study. Each treatment and rearing medium was replicated 5 times. The experimental basins with earthworms were kept in an enclosed room under dark condition and the basins were watered at regular intervals using a fixed amount of water. The basins were covered with moistened newspaper to prevent drying of the media. After 50d, the number of earthworms (adults and juveniles) and number of cocoons produced in each replicate were recorded.

Effect of *Eisenia foetida* activity on nutrients and particle size of compost

The levels of plant nutrients and particle size of compost following vermiculture were determined using two of the above culture media; vegetable refuse alone and a mixture of straw + cow dung + vegetable refuse. The media were prepared and placed in plastic basins as before. Fifteen adults of *E. foetida* were added in to each medium. A control was set up where no earthworms were added to the media. After 45d, the total dissolved N, P, Fe and Mn levels in the media were measured using the colorimetric method.

Particle size improvement (reduction in size of particles) in the media was measured using the Granular metric method (Lavelle et al. 1994). Compost samples were kept at 70°C in an oven for 1h. Thereafter, 50g of the compost sample from each treatment was sieved through mesh (sizes 1mm, 700mm, 500mm, and to 250mm) and weighed separately and compared with the control.

### Statistical Analysis

Two-sample t-test was used to compare the mean abundance of *P. corathrurus* in the two selected sites over the 12 months period. Mann-Whitney test was used to compare the total C, N, and C/N ratio in casts and surrounding soil in each site. Data on the effect of different numbers of *P. corathrurus* on *Z. maize* growth was analyzed using SAS statistical package. Multiplication of the three epigeic earthworms (*E. foetida, P. excavatus* and *E. eugenia*) in the 7 media were analysed using One Way ANOVA and compared using Chi-square. The Chi-square test was used to compare the levels of plant nutrient in vermicompost and in the control.

### RESULTS

#### Year round abundance of *P. corathrurus*

The variation in abundance of *P. corathrurus* adults, juveniles and cocoons in the two selected sites (organic farm and integrated farm) showed a similar pattern in their life cycle stages during the twelve month period (Figures 1 & 2). In both sites a high abundance of *P. corathrurus* was recorded in the months of August and October of 1996/1997. The range for the number of *P. corathrurus* within a quadrate (20 x 20 x 40cm) was adults (4.95-19.6), juveniles (2-13.25) and cocoons (2.2-7.3) in the organic farm site and adults (2.2-15.6), juveniles (1.5-11 ) and cocoons (0.8-4.6) in the integrated farm site.

The fluctuation in the abundance of *P. corathrurus* was observed to be related to rain fall pattern. The abundance of *P. corathrurus* in soil decreased from the months of February to April which are relatively dry months (Figures 1 and 2) at both sites. The numbers increased during the period from May to December when the rainfall was relatively high. Unlike at the organic farm site, where winged beans were cultivated on an extensive scale the typical picture was not observed perhaps due to various soil inputs especially agrochemicals.

The variation in the abundance of surface casts of *P. corathrurus* during the study period is shown Figures 3 and 4. Surface casts too showed a similar pattern of variation with an increase during the months of May – December and a decrease from February to April, with the onset of rains. Furthermore, casts of *P. corathrurus* were readily identifiably. The surface casts were spherical and hence could be easily counted. Thus, it was not necessary to disturb the soil in order to determine the abun-

| Table 1. Number of *P. corathrurus* adults added to different growth media (refer text for details) |
|--------------------------------------------------|
| Code of the Media | No. of earthworms per pot |
| T₁ | Control/ no earthworms |
| T₂ | 3 earthworms |
| T₃ | 5 earthworms |
| T₄ | 7 earthworms |
| T₅ | 9 earthworms |
| T₆ | 11 earthworms |

The total weight of each medium was 900g. Each medium was placed separately in plastic basins (30cm dia. and 15cm height). Each basin containing a specific medium was separately inoculated with 15 mature earthworms of each of the three species used in the study. Each treatment and rearing medium was replicated 5 times. The experimental basins with earthworms were kept in an enclosed room under dark condition and the basins were watered at regular intervals using a fixed amount of water. The basins were covered with moistened newspaper to prevent drying of the media. After 50d, the number of earthworms (adults and juveniles) and number of cocoons produced in each replicate were recorded.
dance of *P. corathrurus* casts unlike for studying the adults, juveniles and cocoon stages. The abundance of *P. corathrurus* surface casts with in a quadrate (20 x 20cm) ranged form 30.0-125.5 in the integrated farm and from 25.5-165.5 in the organic farm.

**pH of *P. corathrurus* casts and surrounding soil**

The pH of worm casts of *P. corathrurus* was found to be higher than that of non-ingested surrounding soil in both fields sites (Figures 3 & 4). The pH of casts ranged from 6.6 - 7.0 and of the surrounding soil from 5.8 – 6.8. Moreover, there was a significant difference (P < 0.05) in the soil pH in the two sites with the soil pH in the Organic farm site being comparatively higher. Furthermore, in the organic farm site there was a significant difference between soil pH and cast pH (P < 0.05) the pH in casts was always higher than that of soil. In the integrated farm, chemical fertilizer had been applied in March/April which has resulted in the disturbance of soil and earthworm casts as well as a reduction in soil pH.

**Carbon content of *P. corathrurus* casts and surrounding soil**

The mean carbon content was found to be higher in *P. corathrurus* casts than in the non ingested surrounding soil in both sites (Table 2). The C content of *P. corathrurus* casts was 5.76% higher in organic farm site and 3.45% higher in integrated farm, compared to the surrounding soil. There was a significant difference between the two sites with respect to total C content of cast and surrounding soil (P =0.05). The overall total C content was higher in the organic farm site than in the integrated farm.

**Nitrogen content of *P. corathrurus* casts and surrounding soil**

Mean N content of casts was higher than the surrounding soil in both sites (Table 2). In the Organic farm, the N content of casts was 0.450 and in surrounding soil it was 0.418. In the integrated farm site the N content of casts was 0.444 and of the surrounding soil was 0.402 (n = 5). There was a significant increase of 9.75% in the N content of casts compared to surrounding soil in the organic farm site and a 6.54% increase in the integrated farm site (P= 0.05)

**C/N ratio of *P. corathrurus* casts and surrounding soil**

The C/N ratio was lower for casts of *P.
Figure 5 pH of casts of *P. corathrurus* and surrounding soil in Integrated farm site at Gannoruwa

corathrurus in both sites when compared to surrounding soil. In the organic farm; C/N ratio of casts was 8.8, and in surrounding soil it was 9.2. In Integrated farm; C/N ratio of casts was 7.9, and surrounding soil = 8.3, (n= 5).

**Effect on the growth of Zea maiz**
The growth of *Z. maize* was significantly increased when different numbers of the endogeic earthworm *P. corathrurus* was introduced into the soil mixture in pot experiments.

After 50 days, a significant increase in the root and shoot dry weight of *Z. maize* were recorded in the presence of earthworms (Table 3). The highest shoot and root dry weight was recorded in treatment with 7 adults per pot. However, treatments T3 and T6 with a higher number of adults recorded a reduction in dry weight of both roots and shoots. Values obtained for plant height, wet and dry weight of shoots and roots were significantly different at P =0.05. The highest plant production in terms of shoot and root dry wet weight was recorded in T4.

**Multiplication of earthworm for vermicompost**
The mean number of cocoons and earthworms (counted separately but pooled together) produced after 50d of introduction of 15 adults of *E. foetida*, *P. excavatus* and *E. eugenia* separately into 7 different culture media is given in Table 4. These levels were analyzed using ANOVA and is indicated in Table 5. A significant difference in the multiplication rate was observed (α = 0.05, P=000) in the different media.

Figure 6 pH of casts of *P. corathrurus* and surrounding soil in Organic farm site at Nawalapitiya

Among the 7 culture media (Table 4) a significant increase in multiplication of *E. foetida* and *P. excavatus* was seen in media with cow dung (C), cowdung and vegetable refuse (C+V) and cow dung, vegetable refuse and straw (C+V+S). These media are thus found to be the best medium for the multiplication of these two species. The best medium for multiplication of *E. eugenia* was found be cow dung and straw (C+S), cow dung, vegetable refuse and straw (C+V+S). Thus, for all three species of earthworms culture media with cowdung alone or in combination with either straw or vegetable refuse was found to give higher multiplication rates than straw or vegetable refuse alone

**Improvement of particle size and nutrients in culture media**
The level of nutrients and the particle size in two of the culture media (C+ V and C+V+S) in which *E. foetida* was cultured was determined after 45 days (Table 5 & Fig. 7). These two media were selected for determining the improvement of the culture media following vermiculture as they gave the highest adult earthworm production levels (Figure 3) When the levels of nutrients in the controls and the treatments were compared using Chi square test a significant difference was obtained (χ² = 38.282 P < 0.05), where the levels of nutrients following vermicompost was always higher than in the control with no earthworms. The results indicated that adequate amount of trace elements were higher in vermicompost than control.

The particle improvement (weight of different particle sizes ranging from 250-1,000µm) in the control media and the media following vermicomposting with *E. foetida* (Fig. 7). The percentage of particle size range 1,000-700µm has decreased following composting in the absence of earthworms while % of particle size in the range 500-250µm has increased in the presence of earthworms, due to cast formation by earthworms.

**Table 2 Carbon and N content of *P. corathrurus* casts and surrounding soil at two sites**

|                  | Organic farm site | Integrated farm site |
|------------------|-------------------|----------------------|
|                  | Casts              | Surrounding soil      | Casts              | Surrounding soil      |
| C%               | 3.86±0.021        | 3.64±0.10            | 3.66± 0.01         | 3.45±0.037            |
| N%               | 0.45±0.016        | 0.41±0.024           | 0.426±0.034        | 0.4±0.015             |
| C/N              | 8.8               | 9.2                  | 7.9                | 8.3                   |
**DISCUSSION**

According study, the rainfall pattern appears to govern the variation in the abundance of casts, adults, cocoons and juveniles of the endogenic *P. corathrurus* in the two sites. The Wet and Intermediate zones of the country (where the two study sites are located) receive relatively low rainfall from the North-East monsoon from December to February. During the dry period the surviving earthworms were observed to be in a state of diapauses as evident form their inactive shrunken state. Furthermore, the clay soil in which they lived formed a compact wall round them. *P. corathrurus* is known to tolerate unfavorable conditions by diapauses mechanism especially during the drought (Fragoso *et al.* 1996) enabling them to survive under extreme climatic condition. With the on set of the South-West monsoons from March to May the abundance of *P. corathrurus* increased, leading to a recovery in their population Furthermore, the higher abundance of earthworms in the organic farm site than in the integrated farm site is likely to be due to the less disturbance of soil during field preparation, increased inputs of organic matter (composting) and the non use of chemical pesticides on crops in the organic farm site.

Production of surface casts throughout the year by *P. corathrurus* unlike certain earthworm species like *Polypheretima elongate* and *Lumbricus terrestris* (Lee 1985) is a useful characteristic in improving soil fertility and physical properties. Moreover, the variation in surface casts of *P. corathrurus* was found to reflect the abundance of the different life stages that live in deeper soil and hence casts could be used as an index of abundance *P. corathrurus* in field studies.

Cast formation by earthworms may be directly facilitated by mixing of organic matter with soil (aggregation), grinding of organic matter in the intestine during digestion (particle improvement), and due to the activity of gut micro flora like Rhyzobia, Vascular Arbicular Mycorhypha and an increase in available plant nutrients (Reddell and Spain, 1991). Release of mineral nitrogen from soil mineralization has been found to be a major activity in their gut during digestion. Furthermore, earthworm activity in soil is known to increase the physical structure of soil by aeration, improvement of water holding capacity and improvement of microhabitat due

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**Table 3 Growth parameters of *Zea maize* 50d after sowing in media with known numbers of *P. corathrurus***

| Treatment          | Root wet weight (g) | Shoot wet weight (g) | Root dry weight (g) | Shoot dry weight (g) |
|--------------------|---------------------|----------------------|---------------------|----------------------|
| TL_Control         | 6.860d              | 36.620c              | 1.5180c             | 5.980c               |
| T1-3 earthworms    | 9.350d              | 50.080c              | 2.4900c             | 7.940c               |
| T2-5 earthworms    | 25.200b             | 78.100b              | 4.1600b             | 11.490b              |
| T1-7 earthworms    | 30.100a             | 142.500b             | 6.7480a             | 21.380a              |
| T3-9 earthworms    | 18.000c             | 91.400b              | 3.9808b             | 11.980b              |
| T6-11 earthworms   | 8.320d              | 42.100c              | 1.4520c             | 6.684d               |
| F value            | 38.77               | 26.15                | 42.87               | 21.92                |
| p value            | 0.0001              | 0.0001               | 0.0001              | 0.0001               |
| LSD Value          | 4.567               | 17.829               | 1.149               | 3.549                |

C= Cow dung  V= Vegetable refuse  S=Straw
Mean values followed by different letters in a row significantly different at P=0.05
The significant positive effect of *P. corathrurus* earthworms on the growth of *Z. maize* is likely due to a combination of interacting factors such as accumulations of earthworm casts rich in C/N, soil aeration due to earthworm movement within the root zone of soil and many other factors as extensively discussed by Fagoso *et al* (1996). The multiplication rates of all three epigenic earthworms were high only when cowdung was a component of the culture medium inferring the important role of cowdung in the diet of earthworms. Cowdung contains digested cellulose and other organic matter and also provides optimum pH conditions for earthworm activity. Epigenic earthworms generally feed on organic matter that is nutritionally low, however partially activated cowdung contains high nutrients and an optimum C/N ratio of 30/1 conducive for earthworm growth (Arenda *et al*. 1999). Earthworm activity resulting from their feeding and metabolism in soil releases nutrients through cast production resulting in the releases of nutrients into soil. Earthworms strongly influence soil N status and N cycling, transferring N from decaying plants that can be easily recycled and taken up by plants (Syers *et al*. 1979). Activity of earthworms in soil or organic matter increase N mineralization via biological processes or through physical changes brought about by the environment. The biological influence of earthworms on N dynamics result from direct and indirect microbial (processes) activity.

N dynamics are directly related to the excretion of N-rich products and turnover of N pool in the earthworm biomass. According to Lee (1985), N containing products of earthworm metabolism are returned to the soil through casts, urine, mucoproteins and dead earthworm tissues. Surface casts usually have a lower C/N ratio than surrounding soil (Syers and Springett 1984). Earthworms ingest dead plant materials of varying C/N ratios and convert them to earthworm tissue with a lower C/N ratio. Increase in particle size that range from 500µm to 250µm improved absorption of nutrients by plants. Symbiotic association between earthworms and microorganisms has led to the break down and fragmentation of organic matter progressively and finally, incorporating it into water-stable aggregates making it available as a plant nutrient. This is one major advantage of vermicompost compared to other methods of composting.
CONCLUSIONS

Year round abundance of *Pontoscolex corathrurus* casts, adults and developing stages was related to rainfall pattern at the two differently managed farm sites. Total C, N content and pH in casts was higher than the surrounding soil. This infers that the impact of *P. corathrurus* on soil is a continuous process while significant increase in plant growth achieved in pot experiments. This is further facilitated by the fact that *P. corathrurus* is the dominant earthworm species in disturbed soils as evident from the study carried by the author.

The three species of earthworms, *Eudrilus eugenia*, *Eisenia fetida* and *Perynix excavatus* can be effectively used for vermiculture and vermicomposting in Sri Lanka. Particle size improvement and available plant nutrients were higher in vermicompost. Therefore, this method of composting is efficient and enriches the plant nutrients. This method of composting could be used to recycle all types of organic waste accumulated in farms, markets and households. The overall activity of earthworms in soil improvement and vermicomposting has not been fully investigated in Sri Lanka and hence requires further research. The commonly found earthworms in disturbed sites are a resource that could be used for improvement of soil fertility and development of large-scale vermicomposting programs ensuring sustainability in agriculture.

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