EFFECTS OF SOIL APPLICATION OF FUNGICIDES ON SOIL POROSITY AND EARTHWORM POPULATION

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ABSTRACT

This experiment was conducted to determine the effects of fungicide application on the soil porosity and survival of earthworm. The experiment was carried out inside the net house of the Department of Agricultural Biology, Eastern University, Sri Lanka. Plastic pots were filled with soil mixture (3 sand: 1 red soil: 1 cow dung) and ten similar sized earthworms were incorporated in each pot. One week after the inoculation of the earthworms, the fungicide *Homai* (Thiophanate methyl 30% + Thiram 30%) was applied to soil at recommended (T_2), 1½ fold (T_3) and 2 fold (T_4), of the recommended dosage and untreated soil mixture (T_1) was the control. The experiment was arranged in a completely randomized design (CRD) with five replications for each treatment. Second application was done at two weeks after the first application. Porosity of the soil was measured at weekly interval. At the end of the experiment, number of survived earthworms in the experimental pots was counted.

Results revealed that, porosity of the soil increased with time in control (T_1). In fungicides treated pots, soil porosity significantly ($p<0.05$) decreased and minimum porosity was measured in T_4. Fungicides inhibit the activities of the earthworms. Therefore in fungicides treated soil mixtures activity and actions of earthworms were found limited and the degree of limitation increased with the concentration of the fungicide applied. There was no significant ($p<0.05$) difference in the number of earthworms survived at the end of the experiment in T_2 and the control. However, significant ($p<0.05$) reduction in the number of earthworms was observed in T_3 and T_4 compared to control. It appears that application of recommended level of fungicide *Homai* does not have any negative effect on the reduction of earthworm population in the soil, however application of higher dosages of this fungicide causes a significant reduction in the earthworm population and shows adverse effect on soil properties.

Key words: Earthworms, Fungicide, Homai, Porosity, Soil aggregates

INTRODUCTION

Earthworms play variety of important roles in agro-ecosystems. Earthworms are important members of the soil biotic community and may enhance soil fertility in agricultural soils (De León *et al.*, 2006). Their feeding and burrowing activities incorporate organic residues and amendments into the soil, enhancing decomposition, humus formation, nutrient re-cycling, and soil structural development. These activities of earthworms increase the porosity and improve the structure of the soil. The porosity of a soil is a determinant factor of soil aeration and soil water holding capacity, which are most essential for crop growth and development. Earthworms make their habitat by tunneling through the soil. Earthworm tunnels loosen the soil to allow air, water and plant roots to move more freely through the soil. The soil properties are essential for the maintenance of soil fertility and sustainable agricultural production in tropical regions (Woomer *et al.*, 1994).

In the Batticaloa district, farmers are using variety of chemicals to control pest and disease problems in crops. They prefer chemical control due to their ample availability, immediate action, easiness of the usage and low labour cost. Fungicides are frequently used to control several soil borne diseases such as root rots, damping off, vascular wilts etc. These fungicides cause subsequent negative impacts on both soil physical and biological properties. Fungicides and fumigants tend to be very toxic to earthworms and could cause population reduction. Reduction in the number of earthworms could cause an undesirable effect on the physical property of the soil. Mainly porosity would have reduced and soil would have compacted. Compacted soils are not conducive for the crop growth and development.

Effects of agricultural pesticides on earthworms depend on the type of chemical used (Werner, 1990). Dosage levels of pesticide also have unique effect on earthworm population and soil properties. In view of the foreseen facts, this experiment was conducted to assess the effects of different dosage rates of a selected fungicide on the soil porosity and the earthworm population.

MATERIALS AND METHODS

Experimental site

This experiment was carried out in the net house of the Department of Agricultural Biology, Faculty of Agriculture, Eastern University, Sri

Lanka from October to December 2007. The average temperature and the relative humidity were 28 ± 1.5 °C and 60 ± 1.4 % respectively during the experimental period.

Experimental design and treatments

Twenty plastic pots filled with soil mixtures were used for the experiment and they were divided into 4 groups according to the treatments. They were arranged in a Completely Randomized Design (CRD) with 5 replications for each treatment.

Figure 1: Arrangement of treatments inside the net house

Homai (Thiophanate methyl 30% + Thiram 30%) was used as a fungicide for this experiment. Untreated soil mixture was treatment-1 (T_1) served as control. Recommended dosage (50 g/ 50 L/ 10 m^2) of the fungicide (*Homai*) was assigned to Treatment-2 (T_2) (Anon., 1997). In treatment-3 (T_3), 1½ fold of the recommended dosage (75 g/ 50 L/ 10 m^2) was added. Two fold of recommended dosage (100 g/ 50 L/ 10 m^2) was incorporated in treatment-4 (T_4).

Preparation of pots

This experiment was conducted using plastic buckets. Soil mixture was prepared in ratio of 3 sand: 1 red soil: 1 cow dung and added to the plastic buckets in equal quantity. A number of ten similar sized, matured earthworms were added into each bucket. One week after the inoculation of earthworms, fungicide was applied to the soil mixture contained in the buckets according to the treatment structure. Second dosage was applied two week after the first dosage.

Measurements

Porosity of the soil

Particle density of the soil was measured at the beginning of the experiment and the bulk density was measured at weekly interval.

Particle density

Weight of empty gravity bottle was taken. Gravity bottle was filled with distilled water and weight was taken. 10 g of soil sample was taken in a beaker and it was saturated with water to expel air from pores. Then soil was boiled to evaporate the water and it was allowed to cool. Soil sample was transferred to gravity bottle and it was filled with water. Then weight of gravity bottle was taken. Particle density was measured using the following equation:

$$\text{Particle density} = \frac{\text{Weight of soil sample}}{\text{Weight of water displaced}}$$

Bulk density

Weight of empty gravity bottle was taken. Gravity bottle was filled with soil sample and weight was taken. Gravity bottle was emptied. Then it was filled with water and volume of water was measured. Bulk density was measured using the following equation:

$$\text{Bulk density} = \frac{\text{Weight of soil sample}}{\text{Volume of soil sample}}$$

Porosity of the soil was measured using the following equation:

$$Porosity(\%) = \left(1 - \frac{BulkDensity}{ParticleDensity}\right) * 100$$

Number of earthworms

Number of earthworms survived in each pot was counted at the end of the experiment (4 weeks after the inoculation). Earthworms were collected by hand sorted and taken to the laboratory for counting.

Data analysis

The measured data were analyzed statistically using analysis of variance (ANOVA) and means were compared by Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Number of earthworms

There was no significant difference ($p<0.05$) found between the control and T_2 (recommended dosage of the fungicide) in the number of earthworms survived at the end of the experiment. Significant reductions in earthworm number were observed in T_3 (1½ fold of the recommended dosage) and T_4 (Two fold of recommended dosage), when compared to the control (Table 1).

Table 1. Number of earthworms persists at the end of the experiment

Treatments	Number of earthworms
T_1	10.0* [a]
T_2	9.8 [a]
T_3	8.2 [b]
T_4	6.4 [c]

*Values are means of five replicates. Means followed by same letter are not significantly ($p<0.05$) different, based on DMRT.

The results of this study showed that the earthworms could survive in the soils, which was treated with recommended dosage of the fungicide. Kirby and Baker (1995) stated that carbendazim and thiophanate methyl prevented the earthworms from feeding at the surfaces but did not kill them. So application of recommended dosages of fungicides to the soil would have not reduced the earthworm population.

These results also revealed that application of higher dosage levels of the fungicides reduced the number of earthworms in the soil. It was reported that, fungicides including benomyl, thiabendazole, thiophanate methyl and carbendazim are extremely toxic to earthworms. Their mode of action is primarily systemic. Due to that, following harmful effects including reduced feeding, retarded growth rates and reduced nerve conduction velocity would have occurred in earthworms. Most contact fumigant nematicides and fungicides are broad-spectrum biocides that can kill most earthworms, even those living deep in the soil (Duiker and Stehouwer, 2003). According to Werner (1990), fungicides like benomyl caused reductions of field populations of earthworms. Reduction in number of earthworms in soil would have created several undesirable effects in the soil structure such as compaction, reduction in soil fertility and poor root growth. This is the reason that, soil porosity was greatly reduced in the T_4 when compared to control (T_1).

Porosity of the soil

It was found that, earthworms increased the porosity of the soil. In all the treatments, porosity of the soil increased significantly in a week after the addition of earthworms. It was also noticed that, there were significant differences ($p<0.05$) in the porosity of soil between the treatments and the control after the application of fungicides (Table 2). In the treatments where the fungicide was applied, the porosity of soil was significantly lower ($p<0.05$) than the control (T_1). In the treatments, soil porosity decreased with the increase in dosage level of fungicide.

Table 2. The effects of earthworms and fungicides on soil porosity

Treatments	Porosity of the soil (%)			
	At the beginning	1st week (one week after the inoculation of earthworms)	2nd Week (one week after the first fungicide treatment)	4th Week (one week after the second fungicide treatment)
T_1	45.84* $^{a(D)}$	47.98 $^{a(C)}$	53.66 $^{a(B)}$	58.24 $^{a(A)}$
T_2	45.44 $^{a(B)}$	48.38 $^{a(A)}$	49.04 $^{c(A)}$	48.32 $^{b(A)}$
T_3	45.89 $^{a(B)}$	48.34 $^{a(AB)}$	50.80 $^{b(A)}$	47.92 $^{b(B)}$
T_4	45.92 $^{a(A)}$	47.48 $^{a(A)}$	47.60 $^{d(A)}$	46.08 $^{c(A)}$

*Values are means of five replicates. Means followed by same (small) letter in each column and means with same (capital) letter in each row are not significantly different at $p<0.05$, based on DMRT.

This experiment analyzed the effects of earthworms on soil porosity and the impacts of fungicides on soil porosity and earthworm population. Results of this experiment indicated that, addition of earthworms to the soil increased porosity. Feeding and tunneling activities of earthworms improve soil structure and increase soil porosity. This was substantiated by Evanylo and McGuinn (2000), who reported that the biological activity of soil fauna improves soil aggregation through the secretion of soil binding mucilages and hyphal growth. Improved aggregation, in turn, increases water infiltration and the ease of plant root penetration.

According to the results of this study, earthworms could be used for the land reclamation processes to improve the soil tilth. Inoculation of earthworms to the compacted hard soils would improve the soil structure and the porosity. They also decompose organic residues and form humus in the soil. Stewart *et al.* (1988) also presented evidence that earthworms initiate the formation of stable soil aggregates in land degraded by mining.

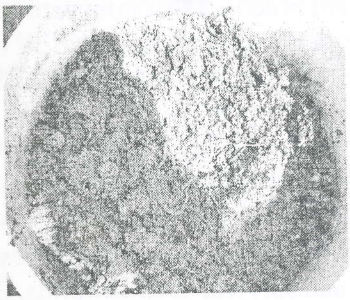

Figure 2: Soil structure at the beginning of the experiment

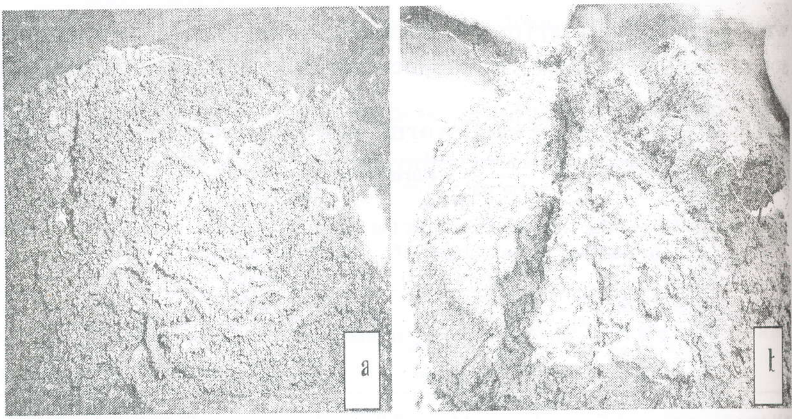

Figure 3: Soil structure at the end of the experiment in un-treated (T 1) soil (A) and in fungicide treated (T 2) soil (B)

This study also showed that application of fungicides to the soil reduces soil porosity. Movements of earthworms in the soil create pores and these pores are later filled by air and water. Earthworm burrows persist as macropores, which provide low resistance channels for root growth, water infiltration, and gas exchange (Zachmann and Linden, 1989). Fungicides retard the growth and development of earthworms and reduce their populations in soil. Earthworms are most sensitive organisms to the external stimulus. Reduction in the activity and population of earthworms would have decreased the soil porosity. This phenomenon increased with the dosage level of fungicide. According to Werner (1990), fungicides and fumigants tend to be highly toxic to earthworms. They may also cause population reduction in earthworms.

From the results of these studies, it appears that, heavy dosage levels of fungicides produce harmful effects to soil macro fauna, in this case earthworms. Loss of earthworms damages the structure of the soil and thereby porosity of the soil would be reduced in the cultivated soil. Agricultural management practices that minimize negative impacts on soil macrofauna and soil organic matter are critical for maintaining the sustainability of agro ecosystems (Woomer *et al.*, 1994; Brown *et al.*, 1994).

CONCLUSIONS

Application of fungicides in recommended rate does not cause adverse effects to soil porosity and survival of earthworms. But higher dosages of fungicides reduce earthworms in soil as a result destroy soil porosity.

Farmers should apply the recommended rate of fungicides while managing soil borne diseases, in order to maintain good soil porosity and conserve the population of earthworms in soil. It is also found in this study that inoculation of earthworms in soil and providing suitable conditions increase soil porosity and improves soil property and they could be used for the land reclamation.

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