Research article

Effects of Earthworm Megascolicidae Population and Litter Quantity on Soil Properties in Experimental Containers

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Abstract Earthworms are important soil animals and perform vital functions in the soil that make better conditions for ecosystem, especially agriculture. Earthworms are involved in decomposing organic matters and mineralizing nutrients, controlling populations of pathogens, improving and maintaining soil structure and mixing organic matters in the soil. In this study, we discussed the effects of earthworm population and litter quantity on soil properties. Earthworm from the family of Megascolicidae was used in this study which is a native family of earthworm in Japan and accounts for more than 95% of earthworm family there. Experimental containers were set in the laboratory where earthworm population and litter quantity were controlled to observe its effect on soil properties. The results showed that, there was tendency of increasing survival percentage of earthworm. The Pearson correlation coefficient analysis showed that with increase in earthworm population and litter amount, there was increasing tendency in soil aggregates and available nitrogen content. The results for available phosphorus content and soil microbes did not show any relation with earthworm number and litter quantity.

Keywords earthworm, Megascolecidae, soil properties, soil aggregates, soil available nitrogen

INTRODUCTION

Nitrogen in soil is mainly bound in organic matter (e.g. litter) and the amount of nitrogen available for plant growth depends on complex interactions between roots, microorganisms and soil animals (Bonkowski et al., 2000). Earthworms play an important role in decomposing plant residue in the short-term through their intensive interactions (Aira et al., 2008; Gomez-Brandon et al., 2010) with the microbial communities. There are approximately 3000 to 4000 different species of earthworms and are distributed according to environment conditions like temperature, soil type, water availability in soil and organic content.

Earthworms are broadly divided into two families, Lumbricidae and Megascolicidae. Also, they are divided into three groups according to their ecological behavior and feeds on leaf litter. Epigiec earthworm, which lives on the surface of soil. Endogeic earthworm, which live in the soil and feed on the soil. Lastly, anenic earthworm, which makes permanent vertical burrows on the soil. All of them feed on leaves on the soil surface and they drag the leaves into their burrows (Bouche, 1977). There are more than 100 species of earthworms found in Japan and more than 95% of earthworms are considered to be those from Megascolecidae family. The earthworm can have notable effects on soil structure where the density of the earthworm is high. According to Brown et al. (2001), earthworms directly affect organic matter behavior by their feeding and casting activity.

Feeding of organic matter by Lumbricidae on organic matter increase in N, P, and K content in soil surface and mounds of earthworm (Darwin, 1881; Salisbury, 1923; Evans, 1948). Different earthworm ecological roles have different effects on soil aggregation and nutrient cycling. But there are few studies on soil properties affected by earthworm population and organic matter quantity. Also, most studies on relationship between earthworm activities and soil properties have been on those from Lumbricidae. The investigation of the change in the effects of Megascolicidae by the number and soil organic matter content should be needed to estimate the earthworm contribution on soil properties in Japan. And the size, abundance and activity of earthworm can change in soil physical and chemical properties.

OBJECTIVE

The objectives of this study were to assess the effects of Megascolicidae population and litter quantity on soil properties in the experimental containers.

MATERIALS AND METHODS

Sampling of Earthworms, Soil and Litter

Epigeic earthworms from Megascolicidae family (Fig. 1) were collected from depth of 5 cm soil using hand-sorting method. Epigeic earthworms are characterized with making transient galleries and are found till 30 cm deep in subsurface soil. The soil used in this experiment was Andosol which are volcanic soils and covers 47% land in Japan. The soil was passed through 2 mm sieve (Fig. 2). Litter were collected from fallen leaves of oak and cereus trees (Fig. 3). The leaves were cut up into small pieces and mixed with soil. All the samples were collected from the same field in Kanagawa prefecture, Japan.

Fig. 1 Megascolicidae used in this study

Fig. 2 Field where samples were collected

Fig. 3 Litter used in this study (mainly oak and cereus)

Experimental Set-up

The size of experimental containers consisted of plastic box was 30 cm in length, 16 cm in breadth and 5 cm in height (horizontal cross-sectional area 1/2100 a) for making similar conditions as the field (Fig. 4). The experiments were conducted for 62 days at room temperature maintained between 10 to 15℃ in the laboratory (Fig. 5).

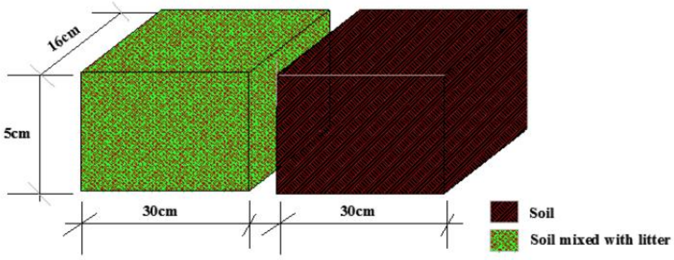


Fig. 4 Schematic diagram of experimental containers

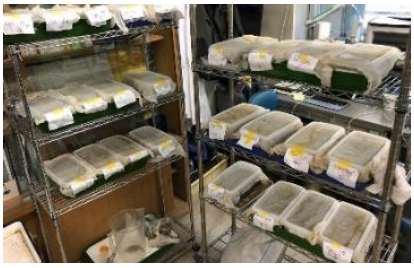


Fig. 5 Experimental containers set in laboratory

The sieved soil was placed in the containers and litter and earthworms were added. Soil and litter were mixed thoroughly. The patterns of soil organic matter content were set into three groups of no added litter of 0% added litter, 5% added litter and 15% added litter. Each group had 5 subgroups of 0, 1, 3, 5 and 10 numbers of earthworms. For 0% added litter group, the five microcosm treatments were named from A1 to A5. Likewise, for 5% added litter group, B1 to B5, for 10% added litter group, C1 to C5, respectively (Table 1). Moisture content for each treatment was tested by using gravimetric method and maintained at 50-60% with regular checking.

Table 1 Experimental treatment patterns

Litter added (%)	Number of earthworms /box	Treatments
0%	0	A1
	1	A2
	3	A3
	5	A4
	10	A5
5%	0	B1
	1	B2
	3	B3
	5	B4
	10	B5
15%	0	C1
	1	C2
	3	C3
	5	C4
	10	C5

Sampling and Parameters Measured

Soil was sampled on 0, 14, 31 and 62 days from the start of the experiments. Soil was sampled from different points from surface of the soil. The samples were mixed thoroughly and analyzed for organic content using ignition loss method, water stable aggregate using Yoder's Method. And, pH was measured using portable pH meter, total available phosphorus using Trough method, total available nitrogen using UV absorption method and colonies of actinomycetes and fungus were analyzed using serial dilution and plate count method, respectively.

Statistical Analysis

Pearson coefficient correlation analysis was performed between 2 mm aggregates, total available nitrogen, organic carbon, pH, total available phosphorus, and biological properties for results obtained during the experiment.

RESULTS AND DISCUSSION

Survival Percentage of Earthworms

Table 2 shows the survival percentage of earthworms with different amounts of added litter. The survival rate under the treatment with no added litter was smaller than others. Treatments where 5% of litter was used, survival rate of earthworms increased slightly compared to treatments without any litter. Treatments with 15% of litter amount showed the highest percentage of survival rate compared to 0% and 5% litter amount treatments. Survival rate of earthworm was in order of

0%> 5%> 15% to the litter amount. This result attributes to the fact that, the amount of feeding material increasing, prolonging the survival rate of earthworms. This tendency that organic matter in the form of litter is the important factor for earthworm survival coincides with that reported in the Brown et al., (2010) which states that earthworms directly affect matter dynamics by their feeding and casting activity.

Table 2 Result of survival percentage of earthworm

Treatments	Number of earthworms 0 day	Number of earthworms 62 days	Survival (%)
A2	1	1	100
A3	3	2	67
A4	5	4	80
A5	10	5	50
B2	1	1	100
B3	3	2	67
B4	5	4	80
B5	10	7	70
C2	1	1	100
C3	3	2	67
C4	5	4	80
C5	10	9	90

Relationship Between Various Parameters of Soil Properties

Significant correlations with 99% significance between 2 mm aggregates and mean weight diameter (MWD) in treatment C5 were shown from the result of Pearson correlation coefficient analysis conducted between all the experiment parameters in 15 different treatments (Table 3). Similar correlation was also found in other treatments. This result is supported by the result of Kladivko et al., (1986) which states earthworm activities increases in MWD and stability of aggregates.

No correlation was found between other parameters except for 2 mm and MWD in all treatments in the applied conditions. The reason for no correlations can be discussed on the behavior of anecic earthworm, in experiment duration and scale, which might have limited the activity of earthworms. It also coincides with results of various researches, such as Lavelle and Martin (2012) which states that earthworm influence organic matter and nutrient during long term genesis.

Table 3 Result of Pearson correlation coefficient analysis of treatment C5

	MWD	>2mm	Organic carbon	pH	Available phosphorus	Available nitrogen	Actinomycetes	Filamentous fungi
MWD	1							
>2mm	0.9917**	1						
Organic carbon	0.7633	0.7216	1					
pH	0.7552	0.8327	0.4360	1				
Available phosphorus	-0.2661	-0.3864	-0.0206	-0.8322	1			
Available nitrogen	0.1707	0.2102	-0.5023	0.2745	-0.2216	1		
Actinomyctes	-0.4791	-0.5212	0.2012	-0.5424	0.3600	-0.9430	1	
Filamentous fungi	-0.5272	-0.4192	-0.4696	0.1457	-0.6662	-0.0801	0.1754	1

*Note) Significant difference at **p<0.01*

Water Resistant Aggregate

Soil aggregates affects porosity, water retention ability, accumulation and decomposition of organic matter in soil (Ketterings et al., 2002; Winsome and McColl, 1998). According to Decaens (2000), Six et al. (2002), earthworm casts are major source of soil aggregates.

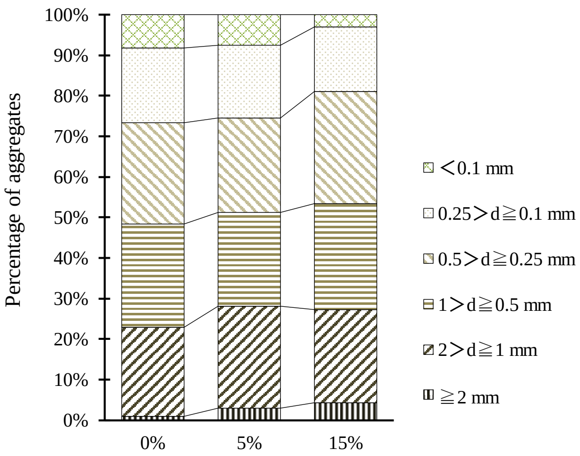


Fig. 6 Initial conditions of aggregates at 0%, 10% and 15% litter

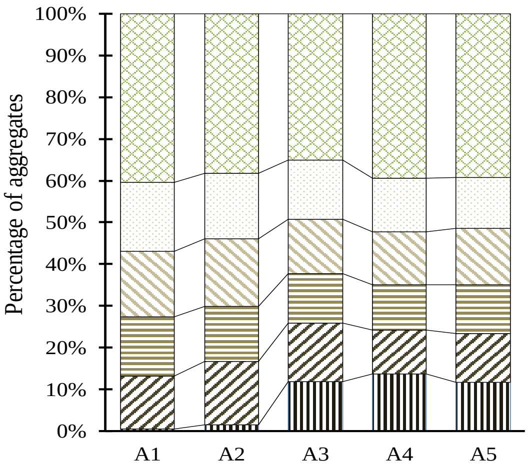


Fig. 7 Changes in the size of aggregate from A1 to A5

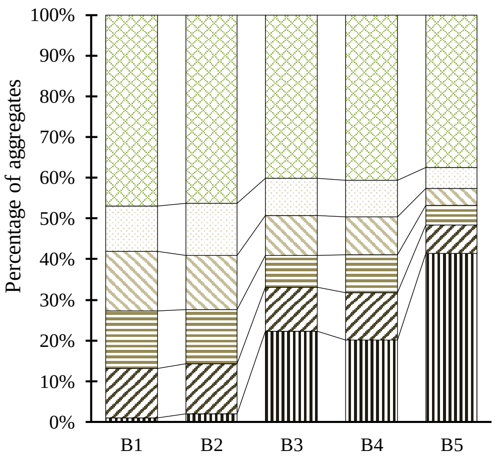


Fig. 8 Changes in the size of aggregate from B1 to B5

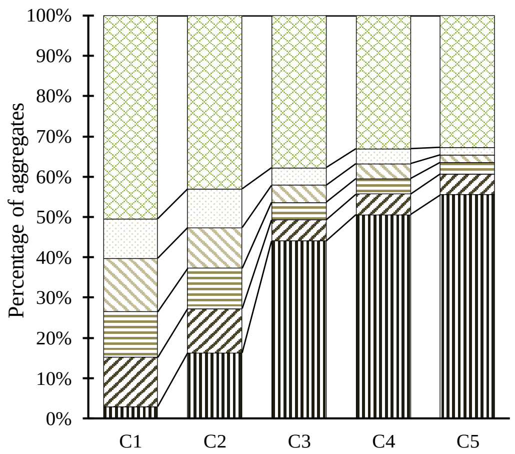


Fig. 9 Changes in the size of aggregate from C1 to C5

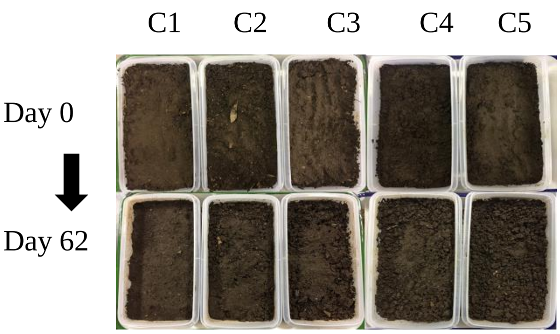


Fig. 10 Changes in aggregates formation in treatments from C1 to C5

Fig. 11 An aggregate formed during the experiment (C5)

It also enhances microbial activity in the soil. The changes in percentage of the aggregation by the amount of litter shown in Fig. 6 shows the initial aggregate concentration in 0%, 5% and 15% of added litter amount. Water resistant aggregate of 2 mm increase with both the number of the earthworm population and litter amount shown in Fig. 7, Fig. 8 and Fig. 9. Treatments with highest number of earthworm population and added litter amount had highest percentage of 2 mm aggregates. Treatment C5, with highest earthworm and added litter had 55% of aggregates formed. From the obtained result, it can be concluded that, litter, a nutrient source for earthworms, greatly influences the formation of water-resistant aggregates.

Available Nitrogen Concentration

Earthworms increase nitrogen content availability for plants (Callaham and Hendrix, 1998) and the activity of earthworms is important to plant nutrition and nitrogen cycling in the soil. The change in available nitrogen by earthworm activity are showed in Fig. 12, Fig. 13 and Fig. 14. The results showed that increase in the number of earthworm population increased the available nitrogen content. A tendency of the highest increase in available nitrogen content was seen in treatment with highest amount of added litter quantity and earthworm population. Earthworms consume large amounts of plant organic matter that contain considerable quantities of nitrogen, and most of the nitrogen that assimilate into their tissue is released to the soil in the form of excreta. It is concluded that organic nitrogen changed into available nitrogen with the action of earthworms from the experiment.

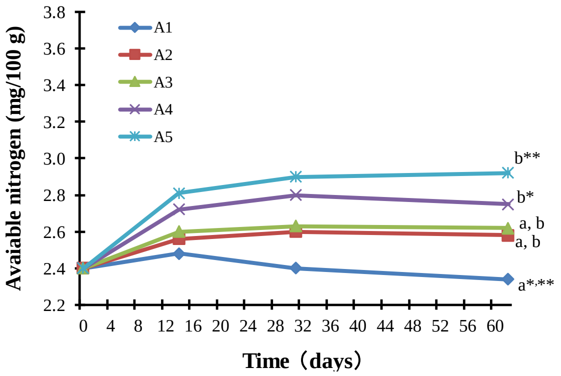


Fig. 12 Changes in available nitrogen concentration of A1 to A5

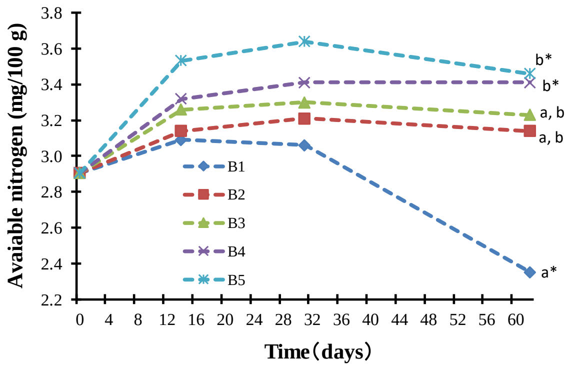
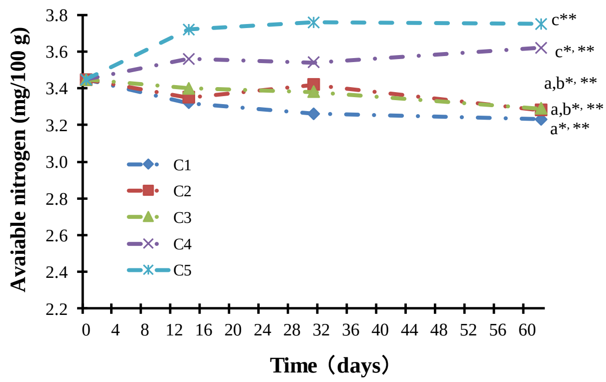


Fig. 13 Changes in available nitrogen concentration of B1 to B5



*Significant difference at **p<0.01, *p<0.05*

Fig. 14 Changes in available nitrogen concentration of C1 to C5

Lunt and Jacobson (1944), Graff (1971) reported that considerably increase in the amount of nitrogen in soil surface in the field condition. Nitrogen in soil is mainly bound in the form of litter and is available to plants with complex interaction of roots, soil microbes and soil animals. Earthworm feeds on litter and release casts which increase amount of available nitrogen. Therefore, incorporation of litter in the soil where earthworm is present can increase casts or aggregates which contains nitrogen. The results also indicate that the more earthworm population and litter, the more increase in casts.

CONCLUSION

This study was conducted to clarify the effects of earthworm population and litter quantity on soil properties by the action of earthworm of Megascolicidae in experimental containers. The results of the experiments showed that, with increase in litter amount, survival of earthworms increased. Similarly, increasing tendency of water-resistant aggregates and available nitrogen was observed. There was no clear relation found in available phosphorus and microbes in the given conditions. In future, to better understand the dynamics of earthworm's action on soil physical and chemical properties, analysis of subsurface soil with depth due to Megascolicidae movements should be conducted.

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