Research article

Changes in Soil Physical and Chemical Properties with Depth due to Megascolicidae Movements

TAKANORI KANEKO
Graduate School of Agriculture, Tokyo University of Agriculture, Japan
Email: taka1504kaneko@gmail.com

TOMONORI FUJIKAWA*
Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan
Email: t3fujika@nodai.ac.jp

MACHITO MIHARA
Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan

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Abstract Earthworms have significant impacts on the physical and chemical properties of soils. It is known that they are remarkably improving soil fertility as well as promoting plant growth because earthworms make castings, which are rich in nitrogen, phosphorus and other nutrients. Additionally, earthworm's movements effects soil properties by their movements in the soil, notably soil aggregates, nitrogen and phosphorus concentration. Earthworms from Megascolecidae family are a major earthworms found in Japan, but there is lack of knowledge on its effect on soil properties compared to other earthworms. Subsequently, this study discusses the changes in soil aggregates, nitrogen and phosphorus concentration changes with depth due to Megascolicidae movements in the soil. An experiment was conducted using cylindrical columns of 12 cm height divided into 3 layers at 4 cm interval. Additionally, two groups were made, with litter and without litter, which were divided into subgroups with variations in earthworm numbers. The results of aggregates showed the tendency of aggregate formation in both the groups, with high formation rate in litter added group. The results of NO_3 and P_2O_5 content significantly differed among the 3 layers in the treatments. The trend of higher NO_3-N and P_2O_5 concentration was observed in middle layer and lower layer respectively. According to the results obtained, Megascolicidae movements effect the distribution of nutrients in subsurface soils.

Keywords Megascolecidae, earthworm movements, soil chemical and physical properties

INTRODUCTION

It is known that earthworms improve soil structure and enhance soil productivity (Barley, 1959b; Lee and Foster, 1991). They promote transport of nutrients and ions in subsurface soil with their bodily movements.

Earthworms are broadly divided into two families, Lumbricidae and Megascolicidae. Earthworms form Lumbricidae family are found in the area from temperate to polar regions of Europe and Asia and those from Megascolicidae family are found in the area from tropical to temperate zones of East and South East Asia. Further, ecologists divide them into three groups into anenic, epigiec and endogeic earthworms based on their habitual preferences (Bouche, 1977). Anenic earthworms are large species, which dig and inhabit upright, make deep burrows in soil and come to surface for feeding. Epigiec earthworms are small species, which lives and feeds on the surface of soil. Many literatures have been made on earthworm from Lumbricidae family on the effects of their activity to the soil properties. Langmaack et al., 1999, estimated that earthworm from Lumbricidae family (*Lumbricus terrestris*) makes 82.3 km/ha of burrows in the agricultural field. These burrows increase air and water permeability, transport oxygen and water and better penetration of roots of the soil (Kavdir and Ilay, 2011). In these literatures, many researches were concentrated on the nutrient availability in the casts on soil surface and the large part of the effects of these casts were clarified, but the knowledge of the effects of the cast in subsurface soil (12 cm depth) which will have significant roles on plant growth was limited. Therefore, this study tries to discuss the effects on soil physical and chemical properties in different layers of subsurface soil released by epigiec earthworm movements in subsurface soil.

OBJECTIVE

The objective of this study is to assess the changes in soil aggregates, nitrogen and phosphorus contents with depth due to movements by epigiec earthworm from Megascolicidae family.

METHODOLOGY

Sampling of Earthworms, Soil and Litter

Epigeic earthworms from Megascolicidae family (Fig. 1) were collected from depth up to 10 cm soil using hand-sorting method. The soil used in this experiment was Andosol, which are volcanic soils and covers 47% of land area in Japan. The soil was passed through 2 mm sieve (Fig. 2). Litter was collected from fallen leaves of oak and cereus trees (Fig. 3). The leaves were made into small pieces before using it. All the samples were collected from the same field in Kanagawa prefecture, Japan.

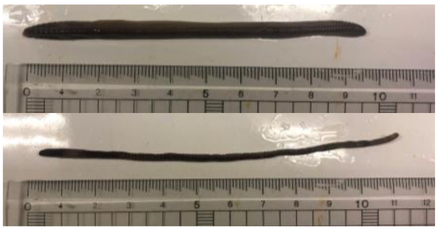


Fig. 1 Megascolicidae used in this study

Fig. 2 Soil used in the study

Fig. 3 Litter used in this study

Experimental Set-up and Conditions

Cylindrical columns of size 15 cm in diameter and 12 cm in height were used having surface area of 0.000018 m^2 for the experimental apparatus. In the experiments, the depth of soil was set 12 cm. The apparatus could be separated into three layers with intervals of 4 cm (Fig. 4). In this experiment, 0-4 cm is assumed as the subsurface soil. The experiments were conducted for 28 days in an incubator whose temperature was set at 17.1 ℃ ± 0.5 ℃ which is similar to the annual average temperature of the area where soil and litter were sampled.

In this experiment, 1.8 kg of soil was used. Patterns of soil organic matter content were set into two groups of 0% added litter and 5% added litter. Each group was further divided into three treatments with 0, 3 and 10 earthworms (Table 1). This experiment was designed with assuming the density of 1 earthworm per one column corresponding approximately 56 earthworms per one hectare. Soil and litter were mixed thoroughly for litter added group. The three column treatments were named from A1 to A3 for litter added group. Likewise, for 5% added litter group, treatments were named from B1 to B3 (Table 1).

The soil in the column was saturated before the start of the experiment by capillary action for 24 hours. After saturation, the excess water was released by gravity for 24 hours. Earthworms were put on the surface of the soil in the start of the experiment. The moisture content of soil for each treatment was maintained at 50 to 60%. To maintain the water content, weight of the treatments was measured on daily basis and equal to lost amount of water was added.

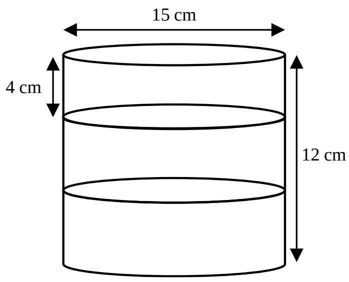


Fig. 4 Schematic diagram of cylindrical columns

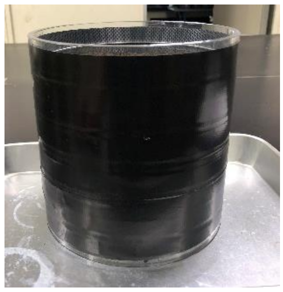


Fig. 5 Column used in this study

Table 1 Column treatment patterns

Litter added (%)	Number of earthworms / cylindrical columns	Treatments
0	0	A1
	3	A2
	10	A3
5	0	B1
	3	B2
	10	B3

Sampling and Parameters Measured

Soil was sampled on 0, 7, 14 and 28 days from the start of the experiments from each layer of 0 to 4 cm, 4 to 8 cm and 8 to 12 cm randomly at 6 different points. The samples were analyzed for water stable aggregate using Yoder's method (Yoder, 1936), total available phosphorus using Troug method (Troug, 1930) and Nitrate nitrogen using Cataldo method (Cataldo et al., 1975).

RESULTS AND DISCUSSION

Survival of Earthworms at Different Layer of Soil

Table 2 shows the change in survival of earthworms at the depth of 0 to 4, 4 to 8 and 8 to 12 cm in 0% and 5 % added litter group at 28 days of experiment. There was no earthworm found in 0 to 4 cm layer in all the groups. The number of earthworms increased with depth. In 0% added litter group, most earthworms were present at 4 to 8 cm layer. Whereas, in 5% added litter group, a greater number of earthworms were present in 8 to 12 cm layer. In B3, 12 earthworms were seen at 28 days, for which an assumption was made that new earthworms were born. With the obtained results, it was proved that the epigiec earthworm from Megascolicidae family used for this study are active in subsurface soil.

Table 2 Result of survival of earthworm at different layer of soil at 28 days

Layer (cm)	A2	A3	B2	B3
0~4	0	0	0	0
4~8	2	7	2	4
8~12	1	2	1	8
Total	3	9	3	12

Periodic Change in Water Resistant Aggregate

The ratio of 2 mm water resistant aggregates increased with time in all layers of the treatments for both the groups (Figs. 6, 7 and 8). High aggregate content was seen in 4 to 8 and 8 to 12 cm layers where the larger number of earthworms existed. Similarly, the Mean Weight Diameter (MWD) of aggregates increased in 4 to 8 and 8 to 12 cm layers with time (Figs. 9, 10, 11 and 12). Group B having added litter content increased aggregates content in all the three layers. It could be explained by the activation of earthworm metabolism by the litter, which provided nutrient to the earthworm.

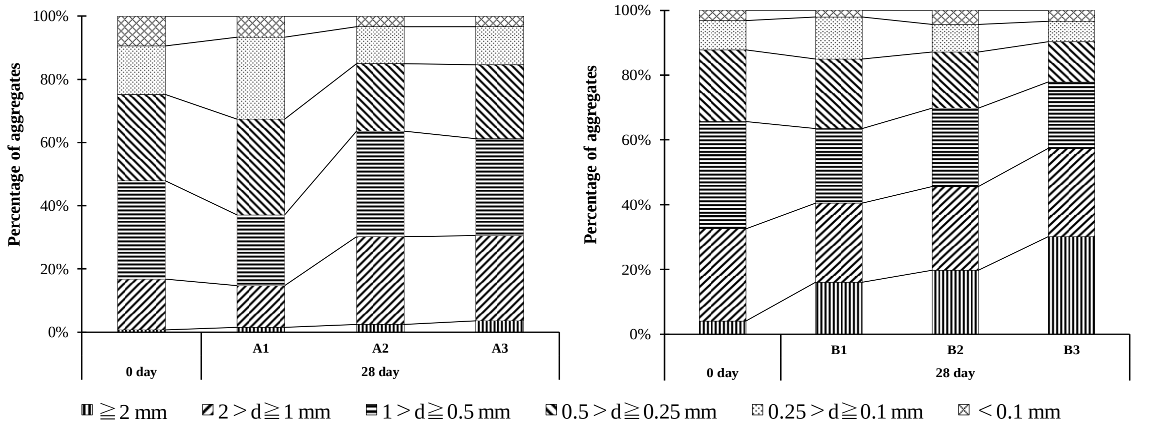


Fig. 6 Changes in aggregate percentage at 0 to 4 cm depth in A and B

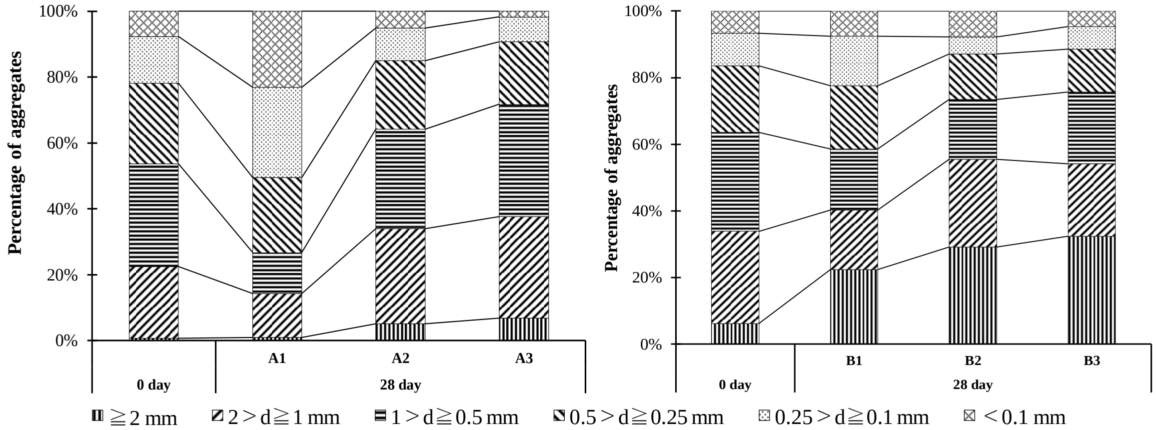


Fig. 7 Changes in aggregate percentage at 4 to 8 cm depth in A and B

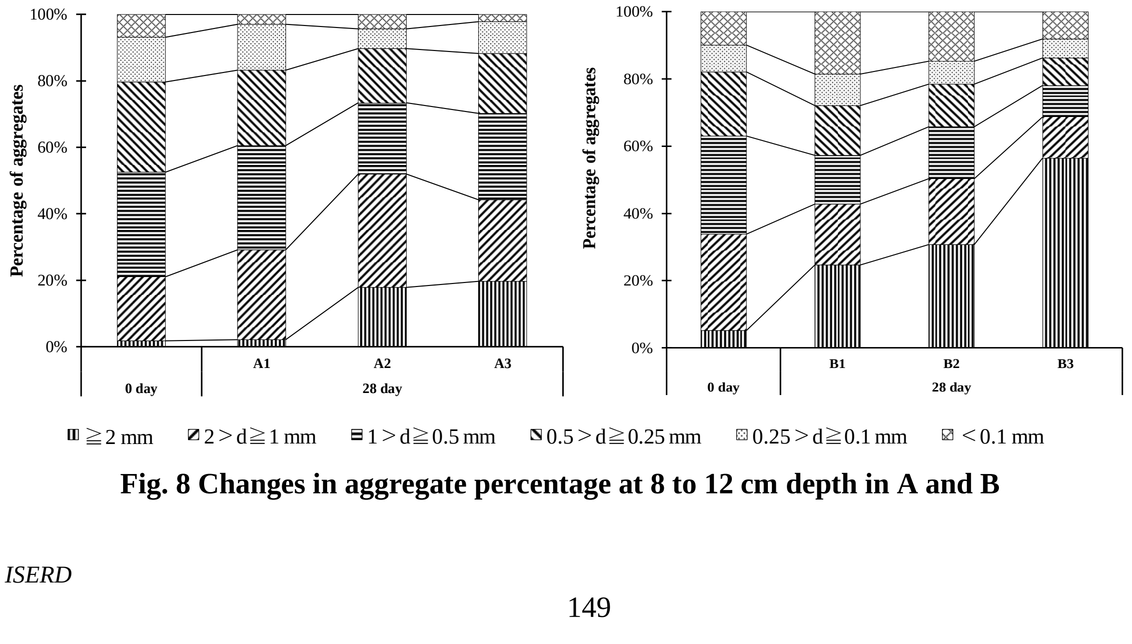


Fig. 8 Changes in aggregate percentage at 8 to 12 cm depth in A and B

The results of this study show that earthworm feeds on soil and litter and releases them in the form of casts. The released casts by the assimilation with soil to form aggregates of 2 mm or larger. This has been also showed in laboratory conditions by Kawaguchi et al., 2011, and in field conditions by Marinissen and Hillenaar, 1997; Ketterings et al., 1997 and Arai et al., 2013. In addition, Kawaguchi et al., 2011, found that 92% of casts weight had 2 mm or more water-resistant aggregates.

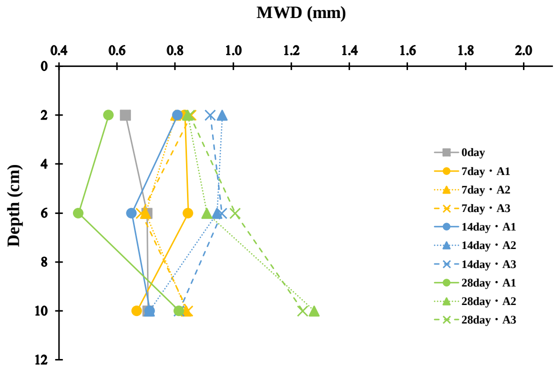


Fig. 9 Periodic changes of MWD content in A1 to A3

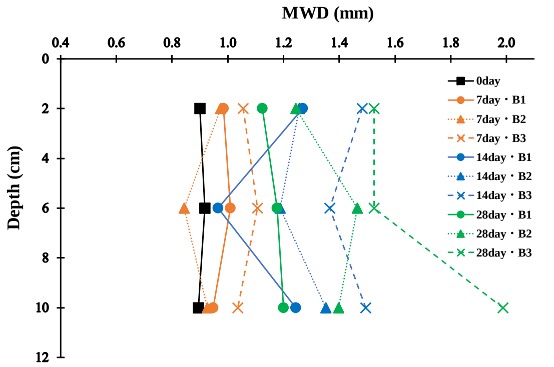
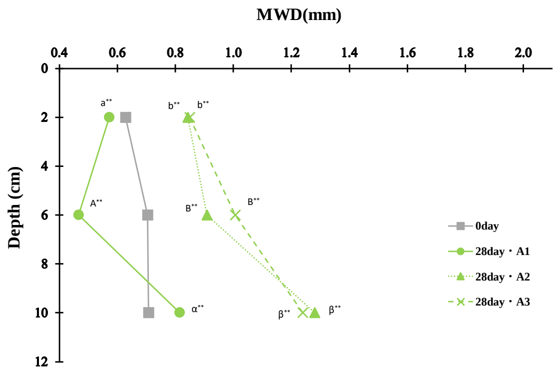
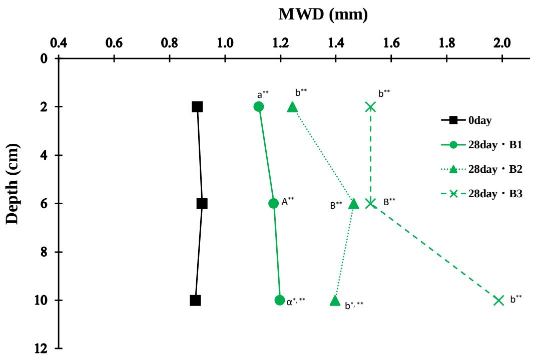


Fig. 10 Periodic changes of MWD content in B1 to B3



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

Fig. 11 MWD content in A1 to A3 at 0 and 28 days



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

Fig. 12 MWD content in B1 to B3 at 0 and 28 days

Periodic Changes in Nitrate Nitrogen Content

The nitrate nitrogen content became higher in all three layers of treatment A2 and A3, with A3 showing comparative high nitrate nitrogen content as shown in Fig. 13. Similarly, the nitrate nitrogen content in 5% added litter treatment B3, increased with time (Fig. 14). Nitrate nitrogen content was highest in treatment B3 in 28 days of experiment (Fig. 16). The highest value was observed in layer of 0 to 4 cm in B3. This increase of nitrate nitrogen content could be explained by nitrification of organic matter enhanced by microbial action present in casts of earthworms. As, B3 had the highest amount of organic matter, it is speculated that earthworm activity was highest in this treatment, resulting in excretion of casts and higher microbial activity. In this process, organic nitrogen gets converted to NH_4-N to NO_2-N, which further changes into NO_3-N. NH_4-N is converted to NO_2-N by the action of ammonia oxidizing bacteria. Whereas, NO_2-N is converted into NO_3-N by the action of nitrite oxidizing bacteria. Nitrifying bacteria are aerobic microbes and are active near surface of soils (Ward, 2008) which supports the result of this study where nitrate nitrogen content was high in upper layer of soil compared to lower layers. According to Su et al., 2017, *Amynthas corticis* from Megascolicidae family has nitrifying bacteria in casts. The results with high nitrate nitrogen content in treatment with high litter content can be discussed with the fact that nitrifying bacteria gets attached in the surface of the litter.

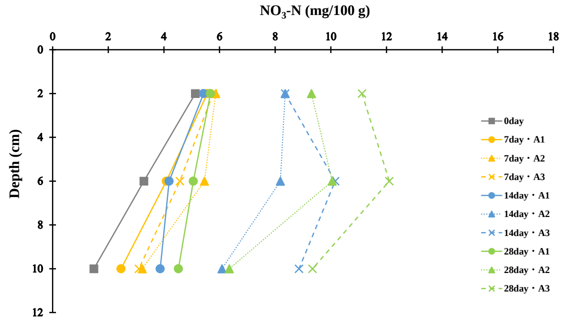


Fig. 13 Periodic changes of NO_3-N content in A1 to A3

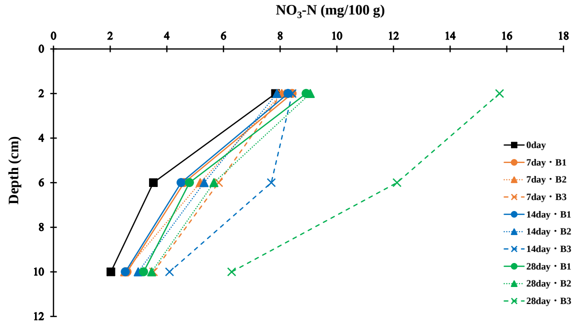
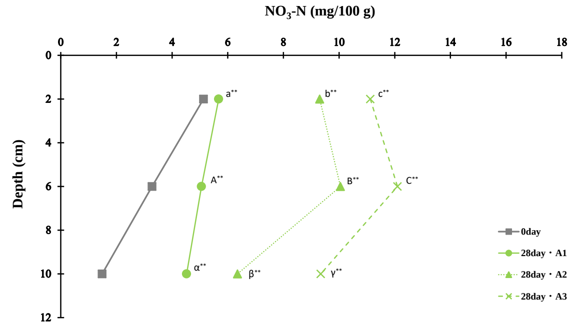
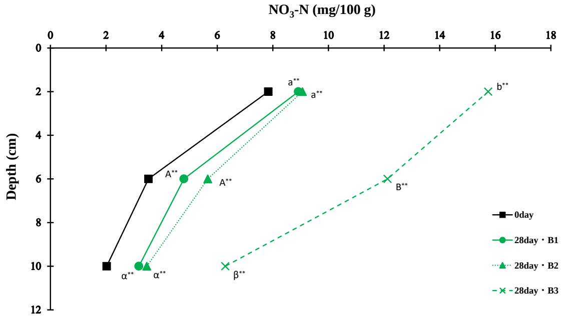


Fig. 14 Periodic changes of NO_3-N content in B1 to B3



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

Fig. 15 NO_3-N content in A1 to A3 at 28 days



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

Fig. 16 NO_3-N content in B1 to B3 at 28 days

Periodic Change in Total Available Phosphorus

High content of total phosphorus in lower layers of column was observed for treatment A3 and B3 contrasting to the results of nitrate nitrogen (Figs. 17 and 18).

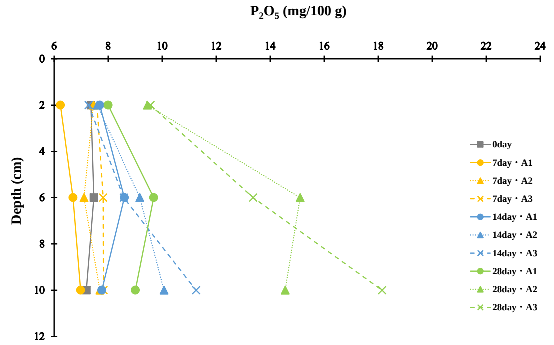


Fig. 17 Periodic changes of P_2O_5 content in A1 to A3

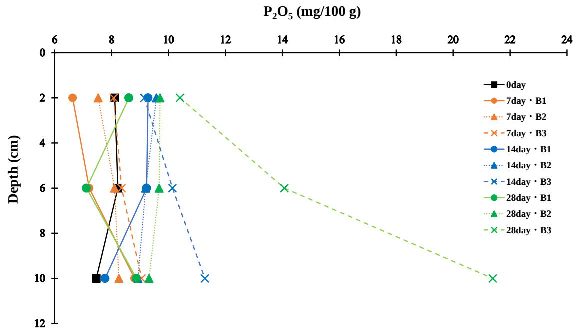


Fig. 18 Periodic changes of P_2O_5 content in B1 to B3

This tendency can be linked with high presence and activity of earthworm in lower layers. It is speculated that high phosphorus content is caused by high phosphatase activity in earthworm casts. High phosphatase activity results in increased inorganic phosphorus released by mineralization of organic phosphorus. Satchell and Martin, 1984 reported high level of phosphatase activity in earthworm casts of *Aporrectodea trapezoide*s, an earthworm from Lumbricidae family. The results of laboratory experiments conducted by Matsumoto and Taniguchi, 1995, hypothesized high phosphatase occurrence in earthworm leading to high phosphatase activity in earthworm casts and surrounding soils.

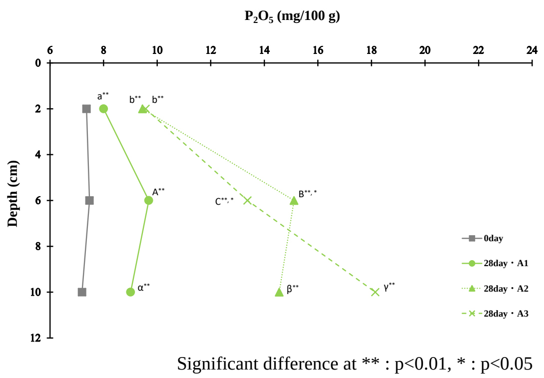


Fig. 19 P_2O_5 content in A1 to A3 at 0 and 28 days

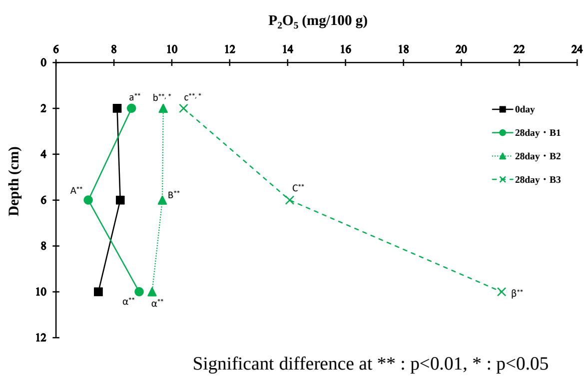


Fig. 20 P_2O_5 content in B1 to B3 at 0 and 28 days

CONCLUSION

This study was conducted to clarify the effects of epigiec earthworm from Megascolicidae family on soil aggregates, nitrogen and phosphorus content with their ecological behavior in subsurface soil using column treatment in incubator. Survival rate of earthworm at different layers resulted in high earthworm number between 4 to 8 and 8 to 12 cm deep, irrespective of litter content. Water resistant aggregates (larger than 2 mm) and MWD increased with time, where the earthworm numbers were high. Similarly, available phosphorus content was high in the layer with high earthworm numbers. This increase can be explained with phosphatase activity in earthworm casts. High phosphatase activity results in increased inorganic phosphorus released by mineralization of organic phosphorus. Whereas, nitrate nitrogen was high in the upper layer having less number of earthworm. The results of nitrate nitrogen content would be due to the presence of nitrifying bacteria in earthworm's casts, which are aerobic microbes and are active near surface of soils. With the obtained results, earthworm activity and movement showed potential for growth and development of plant by enhancing soil structure, increasing nitrogen and phosphorus content.

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