Abundance and biomass of earthworm as affected by long-term different types of soil tillage and fertilization on mungbean plantation at Ultisols

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Abundance and biomass of earthworm as affected by long-term different types of soil tillage and fertilization on mungbean plantation at Ultisols

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Abstract. Long-term tillage and fertilization system have a strong impact on earthworms biomass and abundance in agriculture soils, however, enumerating their influence on mungbean plantation remains little studied. The purpose of this research was to study the effect of continous tillage and fertilization and their interaction on earthworms biomass and abundance under mungbean plantations. Two factors of treatments consisted of tillage system (minimum tillage and intensive tillage) and fertilization (without fertilization and fertilization by NPK (15:15:15) + chicken manure) what has been done since the first (2017) to sixth planting season (2020). The handsorting method was conducted at vegetative maximum and harvest time of mungbeans. The results show that the abundance and biomass of earthworms are significantly higher in minimum tillage compared to intensive tillage as well as fertilization compare to without fertilization. The greatest earthworms biomass and abundance were found in the maximum vegetative of mungbean. The interaction effect occurred at the maximum vegetative observation, namely in intensive tillage, there was no effect of fertilization, on the contrary, at minimum tillage, fertilization increased the abundance and biomass of earthworms. As a consequence, our results indicate that minimum tillage and fertilization significantly improve soil biological quality.
Keywords: Earthworm, Ultisols, Fertilization

1. Introduction

In preparing land for planting cultivated plants, soil tillage and fertilization are usually carried out for providing a good habitat for plant growth. However, if the land is not managed properly, it will result in accelerated soil degradation. One of the important and easy indicators to determine whether there has been a degrated in soil quality is earthworms [1], [2]. In agricultural soils, it usually contains 150-350 individual earthworms per m2, sometimes reaching high populations of more than 400 individual earthworms per m2 which is beneficial for soil fertility and crop production [3], including for the growth and production of mungbean. The presence of earthworms will also fertilize the soil, however some researchers report that earthworms are easy to change with practice of soil tillage [4]

As a bioindicators, the abundance and biomass of organisms in soils, especially earthworms, are strongly influenced by soil management. In general trend, conservation tillage, as consist of no tillage and minimum tillage, tends to increase abundance of earthworm [5], [6]. The results of Sembiring [7] tillage system had a significant effect on the population and earthworms biomass in the land after fallowing for more than 10 years concluded that the abundance and biomass of earthworms in no-tillage and minimum tillage treatments compared to intensif tillage. The distribution of earthworm and biomass at a depth of 0-10 cm was higher than at a depth of 10-20 cm and 20-30 cm in each treatment of the tillage system. This shows that earthworms are very good as an indicators of environmental changes.

Fertilization is also needed in soil management for optimum plant growth. Therefore, the application of NPK compound fertilizer and mixed with manure may also greatly affect the earthworms. In addition, the presence of earthworms will also speed up the decomposition of original residues which will increase the soil organic matter rate and nutrient released [8]. The effect of this fertilization has not been widely reported, especially in combination with the tillage system. Therefore, this research was conducted after the sixth growing season with the same treatment continuously but with different crops, namely rotation of legumes with cereals.

The aim of the study was to determine changes in abundance and biomass of earthworms as affected by tillage system and mixed fertilizers treatment in mungbean fields at Ultisols.

2. Materials and Method

2.1. Study Site

This research was part of a long-term research project that in 2020 had entered its sixth planting period. The research was conducted from September to December 2020 at the Integrated Field Laboratory of Agriculture Faculty, Universitas Lampung in a strategic position, which is located between 5o 22' 11.38" South Latitude and 105o 14' 25.96" East Longitude to 5o 21' 58.35" South Latitude and 105o 14' 43.83" East Longitude.

2.2. Experimental Set Up

The experimental design used was begun in December 2016 to January 2017, hereafter, 2nd was in April to June 2017, 3rd season was in February to June 2018, 4th season was September to December 2018, and 5th season was in February to June 2019 with crop rotation pattern, cereals – legumes (maize-mungbean, etc.). This research was conducted in the 6th season.

The research design was a completely randomized block with 4 treatments: (i) minimum tillage using manual weeding with left litter residue (MT); (ii) minimum tillage + mixed NPK (16:16:16) fertilizers of 200 kg ha-1 + poultry manure of 1 Mg ha-1 (MTF); intensive tillage (IT); and Intensive tillage + mixed fertilizer (ITF). The treatments were repeated across four blocks. Fertilization was conducted by being drawn between rows. Manure application was given 1 time at the same time when planting mungbeans. The application of compound NPK fertilizer was carried out 7 days after planting, before that it was previously thinning the mungbean plant by cutting and leaving 2 perforated plants.

2.3. Earthworm Enumeration

Handsorting methods (25 cm ×25 cm) were performed to enumeration of earthworms which collected from depths of 0-15 cm and 15-30 cm with placed in the middle of the experimental plot [9]. All earthworms and their coccon obtained from each layer were counted. Observations were conducted 2 times, namely at late vegetative and harvest phase of mungbean plantation. The abundance of earthworm were enumerated carefully by hand one by one. One individual of earthworm consisted of coccon and juvenil. Fresh wet earthworms collected were cleaned adn washed in tap water and for measured biomass, earthworm were weighed and then saved in 70% ethanol for further analysis.

2.4. Data Analysis

Two-way factorial analysis of variance (ANOVA)-procedure were used for the abundance and biomass earthworm data. For those that had a significant effect will be tested using the Least Significance Different (LSD). Excel software was used for this statistical analysis.

3. Results and discussion

The results of data analysis showed that the tillage system had a significant effect on the abundance of earthworms, except for observations at harvest at a depth of 15-30 cm. Presumably because many earthworms gather on the soil surface in line with the amount of organic matter and the appropriate microclimate. There was only an interaction effect between tillage and fertilization systems on observations at a depth of 15-30 cm at late vegetative phase. In the calculation of the total earthworms from 0-30 cm depth shows the respective effects of tillage and fertilization systems (Table 1). This

shows that the effect of the tillage system and fertilization does not remain the same in every observation [10] and it has different dynamics depending on the environment at the time of observation [11]. Table 1 also shows that the abundance of earthworms in the upper layer (0 – 15 cm) was higher than in the lower layer (15-30). This shows that earthworms that live in the soil prefer to the top layer which contains a lot of organic matter.

Table 1. Abundance of earthworms and summary of ANOVA as a results of continues tillage system and fertilization on the mungbean plantations and fertilization on the mungbean plantations

Treatments	Late vegetative phase			Harvest phase		
	0 - 15 cm	15 - 30 cm	Total	0 - 15 cm	15 - 30 cm	Total
	..... Earthworms (individulas m^{-2})					
MT	284	72	356	104	40	144
MTF	596	272	868	204	84	288
IT	64	28	92	64	12	76
ITF	112	28	140	76	68	144
ANOVA *F* Value						
Tillage (T)	**16.24 ***	**27.77 ***	**21.34 ***	**8.27 ***	3.08 ^{ns}	**8.82 ***
Fertilizer (F)	4.25 ^{ns}	**13.39 ***	**6.80 ***	3.68 ^{ns}	**15.93 ***	**8.82 ***
T x F	2.28 ^{ns}	**13.39 ***	4.67 ^{ns}	2.27 ^{ns}	0.23 ^{ns}	1.13 ^{ns}

Note: Values followed by * indicate significant treatment effects at the $p < 0.05$ and ns no significant treatment effects.

Abundance of earthworm in minimum tillage treatment on land that was carried out continuously for six growing seasons was significantly higher than intensive tillage at 0-15 cm observations at late vegetative phase of mungbean plantation (Table 2). It shows that the abundance of earthworms is significantly higher in minimum tillage compared to intensive tillage. This indicated that, soil tillage becomes unfavorable soils for earthworms to grow and develop, which is caused by tillage will increase the bulk density of the soil [12];[13], thereby reducing the abundance of earthworms. In addition, due to tillage system, soil organic carbon is rapidly oxidized and lost from the soil system by conventional or intensive tillage [14] so that it becomes a habitat that was not favored by earthworms.

Table 2. Tillage system effect on the abundance of earthworms with the depth of 0-15 cm at late vegetative phase of mungbean plantations.

Treatments	Earthworms (individulas m^{-2})
Minimum tillage	440 b
Intensive tillage	88 a
LSD 5% = 196	

Note: Values followed by different letter indicate a significant difference according to LSD test ($p<0.05$).

At a depth of 15-30 cm and also at a late vegetative phase, it shows that there was an interaction effect between the tillage system and fertilizers treatment, where at minimum tillage, abundance of earthworm was higher in fertilizers treatment that without fertilization, while at intensive tillage there was continuous abundance of earthworm. not significantly different between fertilized and unfertilized (Table 3). Likewise, without fertilization, the abundance of earthworm was not significantly different between minimum tillage and intensive tillage, while in fertilized soil, the abundance of earthworm was significantly higher at minimum than the intensive tillage. This shows that organic matter and undisturbed soil structure can be a good habitat for earthworms [15], especially when the minimum

tillage combined with fertilization will make the abundance of earthworm more abundant and suitable for their growth and development.

Table 3. Effect of interaction between soil tillage and fertilization the the abundace of erthworms with the depth of 15-30 cm at late vegetative phase of mungbean plantations.

Treatments	Minimum tillage	Intensive tillage
	..... Earthworms (individulas m^{-2})	
Non-fertilized	72 a	28 a
	A	A
Fertilized	272 b	28 a
	B	A
LSD 5% = 88		

Note: Values followed by different letter indicate significant different according to LSD test ($p<0.05$). Values followed by capital letters were read by column while by small letters are read by row.

Table 4 shows that in total, both in the observation of the late vegetative phase and at the time of harvest, the abundance of earthworms was significantly higher on the soil with minimum tillage and separately also higher on fertilized soil. Likewise in the harvest phase observation where at 0-15 cm observation, minimum tillage treatment gave significantly higher abundance of earthworm than intensive tillage as well as at 15-30 cm observation significantly higher on land that was fertilized continuously for 6 growing seasons. The addition of nutrients to the soil will affect plant growth which in turn will also affect the soil microclimate such as soil moisture and temperature which is more suitable for fertile plants. Several research results show that soil moisture and soil temperature are higher at minimum tillage in tropical soils [16], however not consistently from year to year both for no-tillage and minimum tillage in a temperate area [17].

Table 4. Effect of continues tillage system, continues fertilizers on the total abundance of earthworms at late vegetative phase and harvest phase of mungbean plantations in the sixth season.

Treatments	Late vegetative phase	Harvest phase
	..... Earthworms (individulas m^{-2})	
Minimum tillage	612 b	6b
Intensive tillage	116 a	112a
LSD 5%	244	80
Non-fertilized	224 a	112a
Fertilized	504 b	216b
LSD 5%	244	80

Note: Values followed by different letter indicate a significant difference according to LSD test ($p<0.05$

Table 5. Effect of countinous tillage system with the depth of 0-15 cm and fertlizers with the depth of 15-30 cm on the abundace of earthworm at harvest phase of munbean plantation in the sixth seasons.

Treatments	Earthworms (individulas m^{-2})	
	0 – 15 cm	15 – 30 cm
Minimum tillage	156 b	
Intensive tillage	72 a	
LSD 5%	68	
Non-fertilized		28 a
Fertilized		76 b
LSD 5%		28

Note: Values followed by different letters indicate a significant difference according to LSD test ($p<0.05$).

The results of data analysis showed that the fertilization and tillage system had a significant effect on the biomass of earthworm on late vegetative phase at 0-15 cm and 15-30 cm observations, but the interaction effect only occurred at 15-30 cm observations, meanwhile on the total biomass of earthworms are not influenced by fertilization. In the observation during the harvest phase, all treatments and observations of different soil depths had no real influence on the biomass of earthworms, except for the observation of total earthworms which were influenced by the tillage system (Table 6). Earthworm biomass observed at harvest time may be due to a stable mass although the abundances are significantly different.

Table 6. Biomass of earthworms and summary of ANOVA as a results of continues tillage system and fertilization on the mungbean plantations at sixth season

Treatments	Late vegetative phase			Harvest phase		
	0 - 15 cm	15 - 30 cm	Total	0 - 15 cm	15 - 30 cm	Total
	..... Biomass of earthworms (g m^{-2})					
MT	9.6	0.5	10.1	5.6	0.5	6.0
MTF	21.6	2.9	22.0	5.8	1.1	6.8
IT	0.8	0.4	1.2	0.4	0.4	0.8
ITF	1.1	0.6	1.7	0.8	0.8	1.6
ANOVA *F* Value						
Tillage (T)	**31.15 ***	**11.34 ***	**25.072 ***	4.43 ^{ns}	0.60 ^{ns}	**5.25 ***
Fertilizer (F)	**5.57 ***	**12.88 ***	4.55 ^{ns}	0.14 ^{ns}	4.05 ^{ns}	0.45 ^{ns}
T x F	5.07 ^{ns}	**8.56 ***	3.82 ^{ns}	0.02 ^{ns}	0.10 ^{ns}	0.02 ^{ns}

Note: Values followed by * indicate a significant difference at the $p < 0.05$ and ns no significant difference according to analysis of variance.

In line with abundance of earthworms, minimum tillage and fertilization also give significantly higher yields than intensive tillage and no fertilization (Table 7). In minimum tillage, previous crop litter and weeds that grow are not removed from outside the land but remain in the field so that they can be sufficient or provide food obtained from litter fall, rhizodeposition, root turnover. In addition, the popuk given is in the form of mixing, NPK and poultry manure which will add nutrition and organic matter. It also shows healthy soil with the presence of organisms that can fertilize the soil such as earthworms that hatch and breed to form high biomass in a comfortable habitat [18]

Table 7. Effect of continues tillage system, continues fertlizers with the depth of 0 - 15 cm on the biomass of earthworms at late vegetative phase of mungbean plantations in the sixth season.

Treatments	Biomass of earthworms (g m^{-2})
Minimum tillage	15.6 a
Intensive tillage	1.0 b
LSD 5%	5.92
Non-fertilized	5.2 b
Fertilized	11.4 a
LSD 5%	5.92

Note: Values followed by differerent letter are significantly different according to LSD test ($p<0.05$

The effect of interaction also occurs in the same way as in abundance of earyhworms (Tabel 8) and same explanation as before.

Table 8. Effect of interaction between soil tillage and fertilization the biomass of erthworms with the depth of 15-30 cm at late vegetative phase of mungbean plantations in the sixth season

Treatments	Minimum tillage	Intensive tillage
	..... Biomass of earthworms (g m^{-2})	
Non-fertilized	0.52 a	0.36 a
	A	A
Fertilized	2.88 b	0.6 a
	B	A
LSD 5% = 1.16		

Note: Values followed by different letter indicate significant difference according to LSD test ($p<0.05$). Capital letters were read by column, while small letters were read by row.

Table 9. The effect of tillage system on the total biomass of earthworm at late vegetative and harvest phase of mungbean plantations in the sixth season

Treatments	Late vegetative phase	Harvest phase
	..... Biomass of earthworms (g m^{-2})	
Minimum tillage	16.04 b	5.48 b
Intensive tillage	1.48 a	3.56 a
LSD 5%	8.00	1.92

Note: Values followed by diffeterent letter indicate a significant difference according to LSD test ($p<0.05$)

Although it was significantly different, namely higher biomass of earthworm at minimum tillage compared to intensive tillage, but the difference was very significant in the observation at the late vegetative phase that is 16.04 g m-2 and 1.48 g m-2 , compared to at harvest phase that is 5.48 g m-2 and 3.56 g m-2, respectively (Tabel 9). This shows that at the end of planting the affect of treatment has begun to decrease, so the best time to observe the life of earthworms due to treatment is during the late vegetative phase, where plant roots in the soil are actively releasing organic acids and optimum plant growth, while in the harvest phase the excretion of organic acids has decreased [19] and the treatment time given is also longer so that environmental stability has occurred between treatments.

4. Conclusion

The biomass and abundance of earthworms on the application minimum tillage system countinuesly were significantly higher than those with intensive tillage systems. The abundance and biomass of earthworms on soil with mixed NPK and poultry manure were significantly higher than those without fertilizer treatment. The tillage system and fertilization interaction have significant effect on the abundance and biomass of earthworms at the late vegetative period observation. At minimum tillage, fertilization significantly increased the biomass and abundance of earthworms, in contrast to intensive tillage there was no difference between fertilized and unfertilized.

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