IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

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To cite this article: A Niswati *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **393** 012027

IOP Conf. Series: Earth and Environmental Science **393** (2019) 012027 doi:10.1088/1755-1315/393/1/012027

Abundance and diversity of soil mesofauna under tillage system in maize plantation at Ultisols soil

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Abstract. Intensification land use with the conventional tillage can bring effects in the soil biodiversity. One of important organisms in soil is soil mesofauna that has an important role in decomposition of organic matter. This research aimed to study the effect of minimum tillage and full tillage on the abundance and diversity of soil meso fauna. The treatments were consisted of soil tillage (minimum tillage and full tillage) and herbicide (with and without herbicide Glifosat 2,4−D) with four replications. The location of this research have soil organic-C and total-N classified in the low criteria. The results show that the application of minimum tillage to prepare maize plantation reached significantly lowest abundance of soil mesofauna compared to full tillage in vegetative phase of maize sampling, however it was not significantly different between minimum tillage and full tillage if it combined with herbicide. Diversity index in full tillage were significantly higher that that in minimum tillage, on the contrary, the dominance index of soil mesofauna were not significantly different between tillage system. On the generative phase, there were no differences on the abundances of soil mesofauna between tillage sistem. There were three dominant mesofauna orders, namely Acarina, Collembola, and Diplopod.

1. Introduction

Soil is the habitat of a number of organisms, such as micro-, meso- and macroorganisms with a variety of metabolisms that play an important role in a number of edaphic processes as well as they play significant roles in function and stability of ecosystems. Use of soil mesofauna as an indicator for soil quality have been reported by several reseacher [1] [2]. Agricultural practice, such as, soil tillage and application of agriculture chemical affected soil characteristic. Decreasing quality of soil biological properties will change food supply for soil mesofauna. Many of the soil mesofauna are sensitive to natural and anthropic disturbances of the environment, which cause changes an abundance and diversity [3].

Nowadays, soil tillage for the preparation of maize cultivation is more intensive, because conventional tillage can facilitate planting and eradicating weeds. Tillage system affected soil chemical and biological in which soil mesofauna lives. In addition, tillage practices change water content, soil temperature, aeration, and decomposition of soil organic matter (OM). Meanwhile, soil organism, especially excistence of soil mesofauna, depend on soil OM whereas conservation tillage increase the storage of soil OM compared to conventional tillage [4]. Beside of tillage practices, generally, herbicide also applied for controlling weed. It was considered as having negative effects on the soil mesofauna community. Controlling weed manually or by machine showed the highest value of population density in Collembola compared to the application of herbicide [5] and the use of herbicides with active ingridient 2,4-D decreases the population density of Collembola [6].

From the above reasons, the concern for the tillage system and herbicide use raise because it has the potential to damage the habitat of soil mesofauna. Therefore, the increasing demand for agricultural commodities, the agronomic practices must be properly protected of native soil mesofauna. Based on the importantly mesofauna as an bioindicator for soil changes, so that the abundance and diversity of soil mesofauna on agricultural soil needs to be studied to determine the impact of soil tillage treatment along with the use of herbicides on decreasing land quality.

The purpose of the research was to study the change of abundance and diversity of soil mesofauna because of tillage and herbicides application in maize plantation at Ultisol soils.

2. Materials and Methods

2.1. Study site.

This research was conducted at ultisols soil in the Integrated Field Laboratory University of Lampung at the location of 5°22'10" South and 105°14'38" East with an altitude of 146 m asl (above sea level) and the Soil Laboratory of the Faculty of Agriculture, University of Lampung from February to July 2014.

2.2. Experimental Setup.

This study was arranged in completely randomized block design with 4 treatments, *i.e.*: MT: minimum tillage (manual weeding); MT+H: minimum tillage + herbicide with active ingredient Glyphosate 2,4 − D (application on 2 days before weed cleaning and 2 days after second fertilization); FT: full tillage (weed remove from plot), and FT+H: full tillage + herbicide. The treatment repeated across four blocks. The size of each trial plot is 3 × 4 m. The spacing used in planting maize is 75 × 20 cm. The herbicide used was Bimastar 240/120 US with a dose of 1.5 l ha^{-1}. The spray volume used is 1,100 L ha^{-1} with a herbicide concentration of 1.4 ml l^{-1} water. Fertilizer application was applied after the maize plant is 7 days after planting (10 tons ha^{-1} cow manure, ½ dose Urea 300 kg ha^{-1}, TSP 100 kg ha^{-1} and 200 kg ha^{-1} KCl) and 30 days (1/2 dose Urea 300 kg ha^{-1}).

2.3. Soil mesofauna enumeration

Soil samples for mesofauna was carried out 2 times during the flowering phase and the harvest phase of the maize plant. Sample for mesofauna were taking by dug soil about 10 cm from five point in each plot and weighting 100 g soil and extracted with modified Berlese-Tullgren methods [7]. The mesofauna obtained was then identified by using a LEICA EZ4 HD compound microscope to the order level. The main variables observed in this study were: soil mesofauna abundance, Shannon-Wiener diversity index, and Simpson dominance index [8].

2.4. Soil dan data analysis

For the supporting data, Soil temperature, soil moisture content, and partial soil analysis (N-total, soil pH, organic C, and C / N ratio) were analyzed referring to Soil and Plant Analysis Methods by Thom and Utomo [9]. All statistical analysis were performed excel software for analysis of variance (if assumption accepted) and correlation between soil characteristic and soil fauna. When a significant effect was observed in the ANOVA, Least Significance Difference (LSD) test at level 5% was performed.

3. Results and Discussion

3.1 Selected soil caracteristic on the harvest of maize

Soil temperature at the harvest phase of maize were not different between treatments (Table 1). While, soil water content in the minimum and full-tillage without herbicide higher than treatments with herbicide *i.e.* 32.3%, 32.5%, 28.1%, and 28.8%, respectively. The results of this analysis show that there is no clear difference between minimum tillage and full tillage, which is thought to be related to the sampling time taken one day after the rain occurs. Rainfall caused water content in organic litter and soil increase to the depth of 0−80 cm. So that, the soil water content and temperature in the tillage treatments did not different except for treatment with herbicide [10].

Table 1. Selected soil characteristics of after maize harvest

Soil properties	Treatments			
	MT	MT+H	FT	FT+H
Temperature (°C)	25.9	25.8	25.9	25.8
Water content (%)	32.3	28.1	32.5	28.8
pH (H_2O)	6.4	6.4	6.9	6.6
Organic-C (%)	1.5	1.5	1.8	1.8
Total-N (%)	0.1	0.1	0.1	0.1
C/N ratio	12.5	11.8	17.5	14.9

Noted: MT: minimum tillage; FT: full tillage; H: herbicide

Soil pH in the FT treatment was higher than that in MT (Table 1) where soil pH in FT include in nuetral and in MT was rather acidic. The results of this study were supported by the results of Ismail [11] who stated that soil pH in no-tillage plot was slightly lower than the moldboard plow treatment to a depth of 12 cm. The low of organic-C and total-N soil are thought to be related to crop history from 2013–2014 where the land were intensifically used for other crop, such as chilly, cucumber, and maize without additional of some organic fertilizer as well as application of full tillage.

3.2 Abundance of soil mesofauna at vegetative maxiumum and harvest time

The LSD test results at the level of 5% (Table 2) showed that the highest population of soil mesofauna was found in FT treatment (262 individuals dm^{-3}) but it was not significantly different from FT+H treatment (213 individuals dm^{-3}) and MT+H (136 individuals dm^{-3}). While the lowest abundance of soil mesofauna was found in MT treatment (35 individuals dm^{-3}) but it was not significantly different from the MT+H (136 individuals dm^{-3}). This is caused by soil mesofauna is more commonly found in soil habitats that have a high porosity [12]. Full tillage resulted in the growth of decomposer microorganisms such as fungi and bacteria increasing rapidly. Fungi and bacteria are the main food sources of soil mesofauna [13] so that the condition of FT indirectly results in an increase in the abundance of soil mesofauna.

The results of the analysis of the diversity of soil mesofauna populations in the maize harvest phase showed that the treatment did not have a significant effect on the soil mesofauna population (Table 2). Population of soil mesofauna in MT, MT+H, FT, and FT+H were 315, 226, 339, and 258 individuals dm^{-3}, respectively.

The period for planting and application of the second herbicide with the harvest phase of maize plants reached 57 days. This condition caused the herbicide active ingredients namely Glyphosate and 2,4-Diphenoxyacetic acid have been degraded in the post-application, so that they did not affect the abundance of soil mesofauna. Herbicides with active ingredients Glyphosate, 2,4-D, Clomazon, and MCPA are herbicides which have low persistence. The duration of this herbicide activity in the soil is 30 days [14]

Increased population of soil mesofauna in all treatments from vegetative phase to the harvest phase of maize (Table 2) is related to the soil conditions that covered by mulch, litter weed and plants that maintained soil mesofauna from the environmental changes. Organic mulch and the presence of weeds increase the population of insects and arthropods in the soil surface such as: Diptera, Aphididae, Thripidae, Aleyrodidae, and Hymenoptera [5].

Table 2. Abundance of soil mesofauna at vegetative maximum and harvest phase of sampling in maize plantation

Treatments	Abundance of soil mesofauna	
	Vegetative maximum	Harvest time
	.... individuals dm^{-3}....................	
MT	35 ± 12 a	315 ± 131
MT+H	136 ± 65 ab	226 ± 64
FT	262 ± 142 b	339 ± 187
FT+H	213 ± 102 b	258 ± 293
LSD 5%	138	ns

Note: Numbers followed by small letter in the same column do not significantly different based on LSD test at 5% level; ns: not significant different. T0: minimum tillage; T1: full tillage; H:herbicide

3.3 Diversity of soil mesofauna at vegetative maxiumum and harvest time

The various types of orders found in each treatment can be seen in Table 5. The number of soil mesofauna orders in the vegetative phase of maize was at a MT and MT+H treatment was 5 orders. While the number of soil mesofauna orders in FT and FT + H treatments was 7 orders.

The number of soil mesofauna orders on FT was higher than that of MT in the vegetative phase of maize plants (Table 4). The results of this study are in accordance with the opinion that tillage from mild to rare causes soil organism communities it will be quickly dominated by a few taxa of soil organisms. The highest increase in the Collembola population was found in the MT treatment of 36 dm^{-3} individuals. Collembola is thought to prefer soil conditions that do not get or are slightly affected by soil activity. This condition is related to Collembola's main food source, namely saprophytic fungi which are associated with decaying plant material [12] .

Order of Acarina increased from the vegetative phase to the harvest phase in maize plantation in the four treatments. Increased population of Acarina in MT, MT+H, FT, FT+H treatment were 204, 35, 87, and 67 individuals dm^{-3}, respectively. The results of this study are suported by reported that Acarina population in conventional or full tillage is higher than that of no-tillage [16]. The highest increase in Diplopod population was found in MT with addition of 25 individuals dm^{-3}. This is thought to be due to existence of litter mulch and weeds in surface soil. Litter mulch and weeds are dead plant material which is the main substrat source of decomposition and accelerates the release of nutrients that can enrich the soil [17].

The results of the 5% LSD test in Table 4 showed that the index of soil mesofauna diversity in FT and FT+H was significantly higher than the treatment of MT and MT+H. Full tillage condition perfectly treated soil results in organisms with a short life cycle, small body size, fast spread, and extensive eating habitats will thrive such as bacteria, nematodes, and Astigmatid mites [13].

3.4. Diversity and dominance index

Based on analysis of variance, effect of tillage system and herbicide have significantly different to diversity index in vegetative phase observation, however there was no significanty different at harvest phase and significant effect on the index of diversity of soil mesofauna in the maize crop at harvest phase as well as the dominancy index. It was assumed that the soil conditions which constituted the soil mesofauna habitat had returned to normal. Nevertheless, there is an increase in the diversity index of soil mesofauna from the vegetative phase to the harvest phase of maize in the MT of 0.5 and MT+H 0.7 compared to FT and FT+H treatment which actually decreases the index of diversity of soil mesofauna 0, 1 and 0.2, respectively. The surface soil conditions of the MT and MT+H treatments which are

Table 3. Diversity of soil mesofauna orders that were found in each treatment.

No	Treatments	Order and the abundances			
		Vegetative maximum		Harvest time	
			individuals dm^{-3}		individuals dm^{-3}
1	Minimum Tillage	1. Collembola	3	1. Collembola	39
		2. Acarina	22	2. Acarina	226
		3. Diplura	3	3. Diplura	6
		4. Diplopod	4	4. Symphyla	6
		5. Unidentified	3	5. Nematodes	6
				6. Diplopod	29
				7. Unidentified	3
	Total		35		315
2	Minimum Tillage + herbicide	1. Collembola	25	1. Collembola	33
		2. Acarina	97	2. Acarina	133
		3. Symphyla	3	3. Diplura	13
		4. Diplopod	7	4. Symphyla	10
		5. Unidentified	3	5. Pauropod	3
				6. Nematodes	3
				7. Diplopod	9
				8. Coleoptera	10
				9. Unidentified	12
	Total		136		226
3	Full tillage	1. Collembola	66	1. Collembola	41
		2.Acarina	98	2. Acarina	185
		3. Diplura	3	3. Diplura	6
		4. Symphyla	3	4. Pseudoscorpiones	6
		5. Diplopod	61	5. Symphyla	9
		6. Coleoptera	19	6. Diplopod	47
		7. Unidentified	12	7. Coleoptera	9
				8. Hymenoptera	3
				9. Unidentified	33
	Total		262		339
4	Full tillage + herbicide	1. Collembola	36	1. Collembola	37
		2. Acarina	95	2. Acarina	162
		3. Diplura	5	3. Diplura	3
		4. Diplopod	38	4. Diplopod	39
		5. Coleoptera	25	5. Unidentified	6
		6. Hymenoptera	8	6. Coleoptera	11
		7. Unidentified	6		
	Total		213		258

covered by weed litter mulch help reduced the effects of environmental changes such as temperature fluctuations and soil evaporation [18].

In general, the dominance index value of the four treatments did not reach or close to 1.0 (Table 5). The most dominant soil mesofauna population in all treatments and all observation is Acarina. Acarina population is highest compared to other soil mesofauna in the upper soil layer at a depth of 0−5 cm. The low dominance index in FT due to being dominated by one type of soil mesofauna *i.e.* order Acarina.

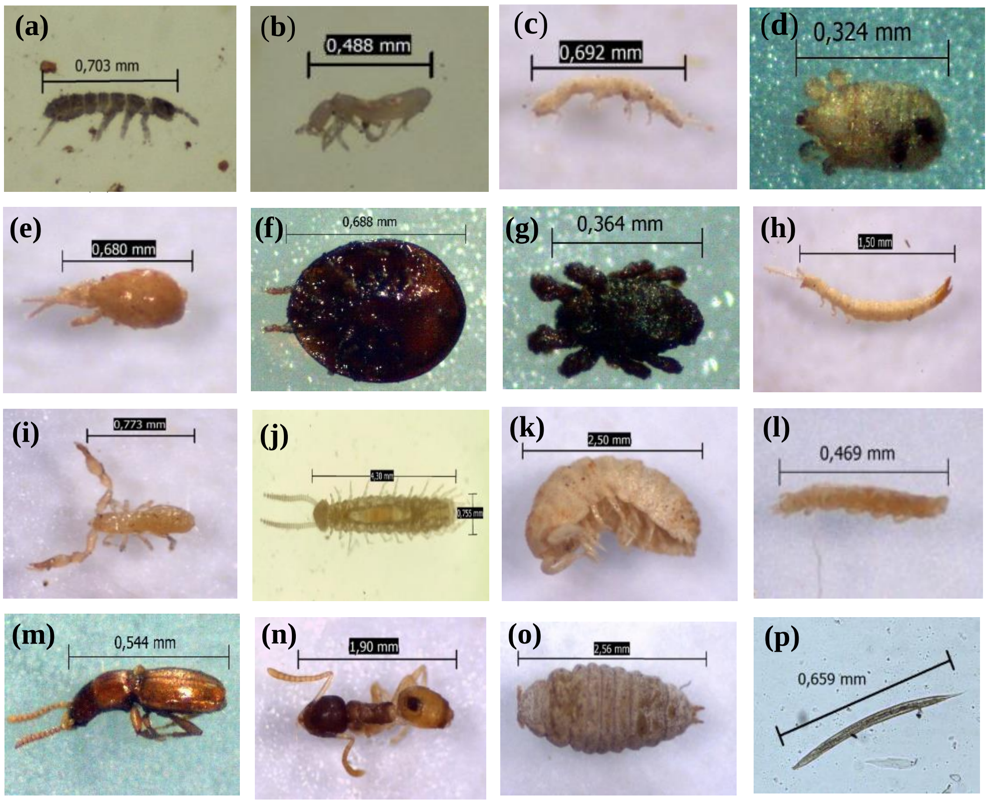

Figure 1. Order of soil mesofauna that founded at the each treatment : (a) order *Collembola* suborder *Entomobryomorpha;* (b) order *Collembola* suborder *Symphypleona*; (c) order *Collembola* suborder *Poduromorpha*; (d) order *Acarina* suborder *Oribatida*; (e) order *Acarina* suborder *Mesostigmata*; (f) order *Acarina* suborder *Prostigmata*; (g) order *Acarina* suborder *Astigmata*; (h) order *Diplura*; (i) order *Pseudoscorpiones;* (j) order *Symphyla*; (k) order *Diplopod*; (l) order *Pauropod*; (m) order *Coleoptera*; (n) order *Hymenoptera;* (o) Unidentified; and (p) order Nematodes.

Table 4. Diversity index of soil mesofauna at vegetative maximum and harvest phase of sampling in maize plantation

Treatments	Diversity index of soil mesofauna	
	Vegetative maximum	Harvest time
	.... H^1	....
MT	0.4 a	1.0
MT+H	0.5 ab	1.2
FT	1.2 c	1.1
FT+H	1.2 c	1.0
LSD 5%	0.3	ns

Note: Numbers followed by small letter in the same column do not significantly different based on LSD test at 5% level; ns= not significant different. MT: minimum tillage; FT: full tillage; H: herbicide

Table 5. Dominance index of soil mesofauna at vegetative maximum and harvest phase of sampling in maize plantation

Treatments	Dominancy index of soil mesofauna	
	Vegetative maximum	Harvest time
	.... D	
MT	0.6 ± 0.3	0.5 ± 0.1
MT+H	0.7 ± 0.1	0.4 ± 0.1
FT	0.4 ± 0.1	0.4 ± 0.3
FT+H	0.4 ± 0.2	0.4 ± 0.1
LSD 5%	ns	ns

Note: ns: not significant; MT: minimum tillage; FT: full tillage; H: herbicide

3.5. Correlation between soil caracteristic and soil mesofauna.

There were no correlation between selected soil caracteristic and soil mesofauna, except for soil pH. Soil pH and abundance of soil mesofauna have significantly relation with the equation of y = 301,5x – 1704 with the coefficient correlatin was 0,6 (n=16). As soil pH increases, the soil mesofauna population increases. The soil pH range recorded in the study was 6.6 (slightly sour) to 7.0 (neutral). The population of endogeic fauna (group of fauna in the soil) will increase from a rather acidic pH to neutral. While the epigeic fauna population (a group of fauna at the surface) such as ants and termites will increase its population at low pH [19].

4. Conclusions

Application of minimum tillage to prepare maize plantation reached significantly lowest abundance of soil mesofauna compared to full tillage in vegetative phase, however it was not significantly different between minimum tillage and full tillage if it combined with herbicide. Diversity index in full tillage were significantly higher that that in minimum tillage, on the contrary, the dominance index on the abundances of soil mesofauna were not significantly different between tillage system. On the generative phase of sampling, there were no differences abundance of soil mesofauna between tillage sistem. There were three dominant mesofauna orders, namely Acarina, Collembola, and Diplopod.

Acknowledgements

The authors sincerely thank to the staff at the Integrated Field Laboratory and Yokohama National University for the financial support for this research.

References

[1] Bedano JC, Domı´nguez A and Arolfo R 2011. *Soil & Tillage Research* **117** 55–60
[2] Socarrás A 2013. *Pastos y Forrajes* **36** 14–21
[3] Scheu S 2002. *European Journal of Soil Biology* **38** 11–20
[4]Jacobs A, Rauber R and Ludwig B 2009. *Soil and Tillage Research* **102** 158–164.
[5] Bandyopadhyaya I, Choudhuri D K and Ponge J F 2013. *Journal of Applied Soil Ecology* **20** (3) 239–253.
[6] Lins V S, Santos H R and Goncalves M C 2007. *Journal of Neotropical Entomology* **36** (2) 261-267.

[7] Karyanto A, Rahmadi C, Franklin E, Susilo F X and de Morais J W 2008. *A Handbook of Tropical Soil Biology*. Earthscan in the UK and USA, pp 85–94
[8] Jørgensen S E, Xu F L, Salas F and Marques J C 2005. Application of Indicators for the Assessment of Ecosystem Health. In: Jørgensen S E, Xu F L (Eds). *Costanca R, and Handbook of Ecological Indicators for Assessment of Ecosystem Health*, CRC Press, Taylor and Francis, London, pp 6–66
[9] Thom W O and Utomo M. 1991. *Manajemen Laboratorium dan Metode Analisis Tanah dan Tanaman.* Universitas Lampung, pp 21-43.
[10] Xu Q, Liu S, Wan X, Jiang C, Song X and Wang J 2011. *Hydrological Process* **26** (25) 3800−3809.
[11] Ismail I, Blevins R L and Frye W W. 1994. *Soil Science Society of American Journal* **58** 193−198
[12] Neher D A and Barbercheck M E. 1999. *Biodiversity in Agroecosystems*. CRC Press LLC. pp 27−47
[13] Lee K E 1991. The Role of Soil Fauna in Nutrient Cycling. In: Veeresh G K, Rajagopal D and Viraktamath C A 9Eds). *Advances in Management and Conservation of Soil Fauna*. Oxford and IBH Publishing CO. PVT. LTD. New Delhi, pp 465−472.
[14] Soerjandono NB 2004. Pengaruh Aplikasi Herbisida Persistensi Rendah pada Dua Cara Olah Tanah terhadap Pertumbuhan Gulma dan Hasil Padi. *Prosiding Temu Teknis Nasional Tenaga Fungsional Pertanian Tahun 2004 Bogor Agustus 2004*. Pusat Penelitian dan Pengembangan Pertanian. pp 192−197.
[15] Gill HK, McShorley R and Branham M. 2011. *Florida Entomologist* **94**(2) 226−232.
[16] Hülsmann A and Wolters V 1998. *Journal of Applied Soil Ecology* **9** 327−332.
[17] Singh J. 1991. Progress in Soil Zoology in India. In: Veeresh GK, Rajagopal D, and Viraktamath C A (Eds). *Advances in Management and Conservation of Soil Fauna*. Oxford and IBH Publishing CO. PVT. LTD. New Delhi. pp 127−139
[18] Alfred J R B, Darlong V T, Hattar S J S and Paul D 1991. Microarthropods and their conservation in some North- East Indian soil, In: Veeresh G K, Rajagopal D and Viraktamath C A (Eds). 1991. *Advances in Management and conservation of soil fauna*. Oxford and IBH Publishing Pvt. Ltd, New Delhi, pp. 309–320
[19] Lavelle P, Lattaud C, Trigo D and Barois I 1995. *Plant and Soil* **170** 23–33