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Research Article

Arthropod and Earthworm Populations on Irrigated Rice Farming Land after Paraquat Herbicide Application

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ABSTRACT

Paraquat dichloride is a herbicide compound commonly used to control grasses and broadleaf weeds. Its use is presently under scrutiny as there is a report that this herbicide is very harmful and hazardous to the environment, especially to wild fauna surrounding farming sites. An irrigated rice farming locale experiment was conducted to observe the effect of paraquat treatment on rice plant biotic environment, particularly its arthropods and earthworm population, two of the most prominent fauna easily affected by paraquat. The study was carried out in Seyegan District, Sleman Regency, Special Region of Yogyakarta Province, on irrigated rice land from October 2018 to February 2019. Four treatments of paraquat, i.e. control (0 kg/ha paraquat), lower dose (0.8 kg/ha), medium dose (1.6 kg/ha), and higher dose (3.2 kg/ha) were arranged. Carbendazim 5 kg/ha was also applied as comparing pesticides, especially for paraquat's effect on the earthworm. The treatments were replicated five times in a plot of 5×5 m^2. The number of arthropods and earthworms was observed in about two weeks intervals or more. The observation was done for the number of arthropods and their families, while for earthworms, only for their numbers. The arthropods population data were subjected to diversity indices and statistical analysis, while the earthworms data were statistically analyzed. The result showed that the arthropod numbers in treated plots were statistically significantly different, but biologically their number was still abundant. Their diversity did not differ from the control treatment at all. The arthropod numbers were 2007, 1483, 1095, 1746, and 1204 in control, lower, medium, higher, and carbendazim plots. The earthworms' numbers were still plenty; those in the higher dosage did not differ significantly from those in control. Their numbers from control, lower, medium, higher dose, and carbendazim plots were 811, 658, 567, 882, and 445 individual earthworms.

Keywords: arthropods; earthworms; irrigated rice; paraquat

INTRODUCTION

Paraquat dichloride is an herbicide-active ingredient compound that has been marketed with several trade names. These paraquat-based herbicides are very popular among farmers and planters, as they are considered effective in controlling weeds in food, horticulture, and especially estate crops. Their intensive (and maybe also extensive) use makes it necessary to pay attention to their use, as they may cause harmful effects to the environment, such as leaving dangerous and unhealthy residues.

Research to obtain original data, facts and information, especially in Indonesia, is sadly lacking. As paraquat is still being used, these kinds of research are essential to decide if this herbicide may be safely used in agricultural commodities or its use should be subjected to supervision or even restricted. Their after-effects to flora and fauna, whether on domesticated or wild ones, of agricultural ecosystems, need to be studied.

Presently, comprehensive studies on paraquat ecotoxicological impacts on Indonesia's biotic and abiotic environments are almost unavailable. Although there are several paraquat related types of research that had been done in Indonesia (for instance, Margino *et al*., 2000; Martani *et al*., 2001;

Martani *et al*., 2004), many of these research were done independently. There were no attempts to compile them into more comprehensive research results with more focused conclusions and information.

The study of paraquat on rice farming, especially in Indonesia, is also rare. A study by Suparni *et al*. (2017) in the modified rice field ecosystem has been done, but the focus was not only on paraquat, as it was only one of the several treatments. Rice cultivation in irrigated rice does not usually employ chemical herbicides. Most practice manual weeding with traditional yet simple tools as the average farmers' planting area is relatively very narrow, less than 0.5 hectares. On the other hand, manual weeding is a more labor-intensive job that presently becomes more difficult to procure as fewer and fewer people are no longer interested in menial jobs. In the future, chemical-based weeding will be much more common, which means that the use of pesticides, including paraquat herbicides, will increase.

With this change in farming practice, pesticides' harmful and hazardous effects may become a severe environmental threat. Therefore, the confirmation on the condition of the environment in the irrigated rice planting areas should be done to ensure whether herbicides application will provide safe and secure protection to irrigated rice farming. This research was carried out to obtain data and information on the effect of paraquat herbicide use in irrigated rice farming. The research was aimed to study the impacts of paraquat herbicide on the ecological aspects of irrigated rice agricultural environments, especially its fauna such as arthropods and earthworms.

MATERIALS AND METHODS

This study was carried out for one planting season in the wet season of 2018/2019 (October 2018–January 2019) on irrigated rice planted in fields where rice has been cultivated continuously every year. The fields are located in Cibuk Kidul Village, Seyegan District, Sleman Regency, Special Region of Yogyakarta. The rice cultivation was done following the commonly practiced rice planting in that area.

The paraquat treatments were arranged as in Table 1. Paraquat treatments were done using an electric knapsack sprayer in a spraying volume of 400 L/ha. The treatment plots were 5×5 m^2 wide, with five treatments and five replications, to a total of 25 plots of 25 m^2 each. Herbicide application was made once for the entire planting season before the grasses, weeds, and last planting season's stubs were cleaned. One treatment with no application was used as control, while another treatment with carbendazim applied one day after planting was used as comparing chemicals. The observations and calculations were then done to the following objects:

Arthropods Population

Two kinds of traps were used to collect arthropods samples from all the field plots. Those were pitfalls and sticky traps. Pitfall traps were made from plastic cups with a top diameter of 7 cm, bottom diameter of 5 cm, and height of 10 cm. Each individual cup was filled to half height with 70–80%, so the arthropod trapped will be soaked without becoming brittle. One to two drops of glycerin were added to lessen alcohol's evaporation. The cup trap was then planted in the ground, with

Table 1. Paraquat treatments applied

Treatments	Paraquat applied (kg ion/ha)	Total paraquat applied in 1 planting season (kg/ha)	Application frequency
Control (PA)	0	0	No application
Lower Dosage (PB)	0.4 (low)	0.8	Pre planting
Medium Dosage (PC)	0.8 (medium)	1.6	Pre planting
Higher Dosage (PD)	1.6 (high)	3.2	Pre planting
Carbendazim (PE)	carbendazim as comparing active ingredient	5	One day after planting

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its upper surface in line with ground level. Over the trap was mounted a thin metal cover of 20×15 cm to avoid rainwater intrusion. Each trap contained a label with location, treatment code, and replication number written on it. After 24 hours, the traps were emptied into a plastic bag marked with information similar to those on the trap and were brought back to the laboratory to be observed and counted. Pitfall trapping result samples were collected first on the day following transplanting and every two weeks afterward up to the 12th week for a total of seven observations.

The second trap, the sticky trap, is a trap that catches arthropods flying over the fields. The trap consists of a 16×20 cm yellow polypropylene sheet embedded with sticky glue. The trap was designed to catch canopy arthropods by mounting the sheet on a stick a little taller than the plants' canopy. These traps were placed on each treatments plots which also serve as replication. Each replication would have three sticks to cover all sides. Arthropods caught were collected 24 hours after the traps were set. The sticky trapping results were collected three times during the entire planting season since the target is different from the pitfall one: one week after treatment (week 1), in the mid of the season (week 7), and by the end of the season (week 13).

Arthropods captured in the samples were then identified and classified according to their taxonomical taxa i.e., orders and families. The identification in the laboratory was done using a light microscope and identification key. The individual arthropod found were counted and separated into orders and families.

Population diversity was measured with a diversity index. The numbers of individual arthropods on each treatment were analyzed using Shannon, Simpson, and Sorenson indices. Shanon index describes species richness in plots with similar treatments; Simpson index to know and compare biodiversity and species/family dominance between plots; while Sorenson index was used to understand the similarity of the individual arthropod in any treated plots. The formula of each index are as follows:

$$\text{Shannon Index } (H') = -\Sigma\, pi\,(\ln pi), \text{ with } pi = \frac{ni}{N}$$

$$\text{Simpson Index } (D) = \Sigma\, \frac{ni\,(ni-1)}{N\,(N-1)}$$

$$\text{Sorenson Index } (C) = \frac{2j}{(a+b)}$$

$$\text{Simpson diversity Index} = 1-D$$

p_i = individual proportion of the i-th species; n_i = the number of individual of the i-th species; N = total number of individual; a = the number of individual in A area; b = the number of individual in B area; j = the lowest number of individual between A and B areas.

Earthworms Population

The treated soils and control were observed for their earthworms population. The samples were first collected on the day before treatments and afterward started at the same time with the pitfall collecting. The worms were taken from a 50×50 cm sample site on each plot with 20 cm depth and replicated five times. The earthworms were separated from the muddy soil and counted.

All obtained data were then subjected to LSD test (α = 0.001), followed by DMRT (α = 0.05), using "R" statistical analysis program version 3.5.2. "Eggshell Igloo."

RESULTS AND DISCUSSION

Arthropods Population

The number of individual arthropods found in the pitfall traps during the planting season in the irrigated rice area after paraquat treatments is shown in Table 2. Even though the number in the control treatment was significantly different from other treatments, with a little more than 2000 individuals, their numbers do not differ significantly. Furthermore, the actual numbers on biodiversity indices are still very agreeable, as shown in Table 3.

Table 3 shows the number of orders and families in each paraquat plot and those found on the control and carbendazim treatment plots captured in the pitfall traps. These orders and family numbers are the basis for the calculations of arthropod diversity indices. Although the individual number of the arthropods on control plots was found to be higher than in other treated plots, the average number of

Table 2. The number of individual arthropods found on the irrigated rice area after paraquat treatments

Treatments	Sampling of (in number of the individual)							
	1st	2nd	3rd	4th	5th	6th	7th	Total*
Control (PA)	77	517	507	463	277	96	70	**2007 a**
Lower Dosage (PB)	51	177	330	454	254	115	102	**1483 b**
Medium Dosage (PC)	20	124	359	242	154	65	131	**1095 c**
Higher Dosage (PD)	12	269	399	579	296	98	93	**1746 b**
Carbendazim (PE)	54	243	295	177	170	104	161	**1204 c**

Note: *Number in Total with the same letter are not significantly different (LSD 0.001, DMRT 0.05).

Table 3. Calculations of arthropod population diversity indices caught by pitfall traps after paraquat treatments

Group	PA	PB	PC	PD	PE
Σ Orders	9	8	8	9	9
Σ Families	32	28	28	30	30
Σ Individual	2007	1483	1095	1720	1720
Diversity (H')	4.208	3.698	3.858	3.885	3.885
Richness	1.998	2.269	2.144	1.813	1.813
Evenness (e')	0.522	0.572	0.651	0.539	0.538
Dominance	0.365	0.217	0.286	0.409	0.409

Note: PA = control; PB = lower dosage; PC = medium dosage; PD = higher dosage; PE = carbendazim.

orders in the control treatment was about the same with all treatments. In contrast, the number of the family are very slightly higher. The results of the calculation are presented in Table 3.

All the Diversity Indices in Table 3 are bigger than 3. That means the diversity in all treatments is high since the Diversity or Sorensen Index (H') values are considered low if it is less than 1, moderate if valued between 1 and 3, and high with a value of more than three. The treatment results in indices ranging from 3.69771 (lower dosage) to 4.20809 (control), but all are more than 3. With 8 to 9 orders and 28 to 32 families on these treatments, the biodiversity indices indicate no degrading effect of paraquat treatment on the arthropods fauna. The finding is unlike the result of Snider *et al.* (1985); Gbarakaro and Zabbey (2013); Sartori and Vidrio (2018), which found that paraquat is less toxic to soil microfauna than other herbicides since its degrading effect is mitigated by soil inactivation.

Other indices such as richness, evenness, and dominance also indicate the arthropod population. The low richness values show that the number of orders in the plots was not many, but those were found in all treatments. With evenness and dominance, they show that the number of the orders and families spread out evenly in all treatment plots. No family is dominant over the others, as the indices are low, denoting evenness and no dominance.

The sticky traps, which had different targets (i.e., flying arthropods above the canopy), were observed at different times with the pitfall traps, and only three times during the season based on the flying arthropods' behaviors, and the data were presented in the form of average catches of each treatment. The result is shown in Table 4.

The Diversity Indices for flying arthropods captured by sticky traps are high and higher than the Diversity Indices of the arthropods caught by pitfall traps (Table 4). Their values range from 5.4468 to 6.3803, which denotes a fairly high diversity. This high biodiversity can also be observed from the number of orders and families. Although the orders numbers are about the same as those from the pitfall traps' catch (between 7 to 9 orders), the numbers of the families on each order from the control and treatments plots are slightly higher than those from

Table 4. Calculations of arthropod population diversity indices caught by sticky traps after paraquat treatments

Group	PA	PB	PC	PD	PE
Σ Orders	8	9	8	7	9
Σ Families	33	38	37	33	34
Σ Individual	274	330	483	356	355
Diversity (H')	5.701	6.380	5.825	5.447	5.620
Richness	2.896	2.789	2.531	2.630	2.360
Evenness (e')	0.836	0.773	0.706	0.759	0.675
Dominance	0.175	0.197	0.360	0.202	0.237

Note: PA = control; PB = lower dosage; PC = medium dosage; PD = higher dosage; PE = carbendazim.

Table 5. The number of earthworms found after paraquat treatments

Treatments	Sampling of (in number of the individual)							
	1st	2nd	3rd	4th	5th	6th	7th	Total*
Control (PA)	0	5	171	253	248	87	47	**811 ab**
Lower Dosage (PB)	0	8	120	14	123	39	223	**658 bc**
Medium Dosage (PC)	0	12	83	141	96	29	206	**567 c**
Higher Dosage (PD)	0	11	213	221	119	115	203	**882 a**
Carbendazim (PE)	0	3	105	149	73	14	101	**445 c**

Note: *Number in Total with the same letter are not significantly different (LSD 0.001, DMRT 0.05).

the pitfall traps. The total number of families in those plots ranged from 33 to 38, a little more than those found on pitfall traps.

Other indices of richness, evenness, and dominance also show that their values did not differ so much between treatments. The findings on the number of orders and families on both treatments and control, which are high and almost do not differ from each other, show that the paraquat treatment does not cause depletion on the kinds of arthropods in the field. Their number steadily thrived, and both the control and the treatment plots did not show any drastic changes after using paraquat herbicides. Badejo (2004) had already noted that some herbicides, including paraquat, do not affect the arthropods population after their application since the main target is weeds, i.e., plants. Albajes *et al.* (2009), in their study, found a similar phenomenon: in plots treated with herbicides, some phytophagous arthropods such as thrips and aphids did not significantly differ from those on the untreated plots, while predators population in treated plots also behaved similarly, they did not show a significant decrease.

Earthworms Population

Earthworm populations were observed before the treatment when the soil was still dry, and the earthworms could not yet be found in the soil. The number of individuals in the first observation of all treatments, including control, is therefore zero. But after the rain came and the planting season began, there were already earthworms in the muddy soils from any treatment plots. The number of earthworms found in the observations is presented in Table 5.

Only carbendazim treatment affects earthworms into the lowest number of individuals in the population, although the total was still fairly high. Other treatments are close to controlling treatments, and two of them (lower and higher dosages) do not differ significantly from control. This means that the paraquat treatments do not change the earthworm population in the soil. The finding confirms what was reported by Wang *et al.* (2012) and Muangphra *et al.* (2017). A study by Wang *et al.* (2012) found that common earthworm *Eisenia fetida* survived herbicide treatments provided there were soil layers that would help herbicides

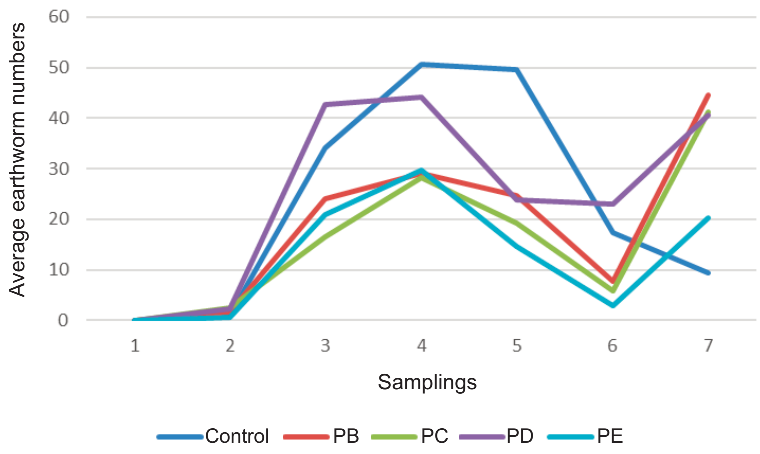

Figure 1. The average numbers of earthworms after paraquat treatments (PA = control; PB = lower dosage; PC = medium dosage; PD = higher dosage; PE = carbendazim)

resorption and render them harmless to microfauna. Muangphra *et al.* (2017), with their study on earthworm *Pheretinia peguana*, concluded the same: the least toxic level of herbicides is when they are applied to the soil.

Figure 1. shows the dynamics of the earthworm population during the season. The population patterns are about the same: the low number at the beginning peaked at the middle and then started to slide down. These may be explained through the soil condition during the planting season. The dry condition at the beginning and toward the end limits the earthworm population number. At the same time, the muddy soil in mid planting season provides the ideal condition for the earthworm to grow and develop.

CONCLUSION

The use of paraquat in rice paddy soil did not affect much soil fauna, i.e., arthropod and earthworm. It should be noted that the treatment must be done carefully and use the medium dosage as suggested by the result.

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LITERATURE CITED

Albajes, R., Lumbierres, B., & Pons, X. (2009). Responsiveness of Arthropod Herbivores and Their Natural Enemies to Modified Weed Management in Corn. *Environmental Entomology*, *38*(3), 944–954. https://doi.org/10.1603/022.038.0349

Badejo, M.A., (2004). The Interphase between Entomology and Acarology in Ecosystem Engineering and Ecotoxicology, Inaugural Lecture Serial 169. Ile-Ife, Nigeria: Obafemi Awolowo University (Press Limited).

Gbarakaro, T.N., & Zabbey, N. (2013). Soil Mesofauna Diversity and Responses to Agro-Herbicide Toxicities in Rainforest Zone of the Niger Delta, Nigeria. *Applied Journal of Hygiene*, *2*(1), 1–7. Retrieved from https://www.idosi.org/ajh/2(1)13/1.pdf

Margino, S., Martani, E., & Sunarminto, B.H. (2000). Paraquat Herbicide on Peat Soil: I. Its Effects on the Dynamics of Microbial Population. *Jurnal Perlindungan Tanaman Indonesia*, *6*(2), 91–100. Retrieved from https://jurnal.ugm.ac.id/jpti/article/view/12386

Martani, E., Margino, S., & Magdalena, M. (2004). Paraquat Toxicity on Root Nodule Formation on *Macroptilium atropurpureum* and Its Connection with Population of *Rhizobium* sp. *Jurnal Perlindungan Tanaman Indonesia*, *10*(2), 87–96. Retrieved from https://jurnal.ugm.ac.id/jpti/article/view/12119

Martani, E., Sunarminto, B.H., Supriyo, A., & Margino, S. (2001). Herbisida Parakuat dalam Lahan Gambut: II. Pengaruhnya terhadap Pertumbuhan dan Hasil Kedelai. *Jurnal Perlindungan Tanaman Indonesia*, *7*(1), 22–31. Retrieved from https://jurnal.ugm.ac.id/jpti/article/view/10017

Muangphra, P., Kwankua, W., & Gooneratne, R. (2014). Genotoxic Effects of Glyphosate or Paraquat on Earthworm Coelomocytes. *Environmental Toxicology*, *29*(6), 612–620. https://doi.org/10.1002/tox.21787

Sartori, F., & Vidrio, E. (2018). Environmental Fate and Ecotoxicology of Paraquat: A California Perspective. *Toxicological & Environmental Chemistry*, *100*(5–7), 479–517. https://doi.org/10.1080/02772248.2018.1460369

Snider, RJ., Moore, J.C., & Subagja, J. (1985). Effect of Paraquat and Atrazine on Non-target Soil Fauna. In F.M. D'Itrii (Ed.), *A System Approach to Conservation Tillage* (pp. 138–147). Boca-Raton, United States: CRC Publishing.

Suparni, Putra, N.S., & Suputa. (2017). Population of Herbivorous and Carnivorous Arthropods in Rice Field Ecosystem Modified with Vermicompost and Flower Plants. *Ilmu Pertanian (Agricultural Science)*, *2*(2), 48–55. https://doi.org/10.22146/ipas.16983

Wang, Y., Wu, S., Chen, L., Wu, C., Yu, R., Weng, Q., & Zhao, X. (2012). Toxicity Assessment of 45 Pesticides to the Epigeic Earthworm, *Eisenia fetida*. *Chemosphere*, *88*(4), 484–491.