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EFFECTS OF HERBICIDES ON SOIL MICROARTHROPODS RICHNESS AND DISTRIBUTION IN TROPICAL SOILS IN NIGERIA

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ABSTRACT: This study investigated the effects of herbicides on soil microarthropods richness and distribution conducted from August to December 2017 in tropical soils in Nigeria. A split-plot design with six replicates arranged in a Randomized Complete Block Design was adopted. The doses for glyphosate were treated to the plots as low (1.4ml/m^2 active ingredient), standard (2.8ml/m^2 a.i) and high (5.6ml/m^2 a.i), and for multrazine, as low (2.1ml/m^2 a.i), standard (4.2ml/m^2 a.i) and high (8.4ml/m^2 a.i) with a control included. Moist soil samples were randomly collected from treated and control plots with an 8.5 cm^2 diameter bucket-type auger at the depths of 0-5cm, 5-10cm, 10-15cm, and 15-20cm between the hours of 8 to10am. A total of 14 soil microarthropods comprising Cryptostigmata (8), Mesostigmata(3)and Collembola(3) were recorded. Oribatid mites- *Scheloribates sp., Galumna sp.,* and *Bicrythermannia sp.* were the dominant groups recorded at each sampling period. The highest number of soil microarthropods was recorded from the control plots. The study revealed that both glyphosate and multrazine herbicides have effect on the richness and distribution of soil microarthropods, though the effect of multrazine was highly severe. Therefore, *Galumna*, *S. yorubanensis* and *B. nigeriana* tolerated the herbicides and could be used as monitor species. Both herbicides completely eliminated collembola from the treated plots. In all the treatments, fewer soil microarthropods were recorded as soil depth increased. The ecological impact of this study is that glyphosate is environmentally friendlier than multrazine herbicides to agro-ecosystems. Similarly there was a statistical difference between the treatments.

KEYWORDS: Herbicide, Soil microarthropods. Species Richness, Mites, Collembola.

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1. INTRODUCTION

Soil microarthropods, particularly, Oribatid mites and collembolans are the most abundant and diverse arthropods living in the soil and litter environments [7, 27]. The dominance of these groups, which possess specialized morphological adaptations such as thick cuticles (Cryptostigmata) and very broad tolerance limits [8,16] enabling them to thrive in environments that seem to be adverse for other groups [30] which in some cases, qualified them as bio-indicators that represent different aspects of soil quality in different ecosystems[8,7and 17]. Members of the microarthropods group are unique not so much because of their body size but for the methods used for sampling them. The composition and abundance of the soil microarthropod assemblage can be determined by several factors, including interactions with other soil inhabitants (nematodes, enchytraeids, fungi, and bacteria), as well as soil organic matter contents [14], temperature, moisture, pH, [13], and compaction [11]. Thus, changes in these conditions might affect the abundance and distribution of soil microarthropods [18]. Soil microarthropods occur mostly in the upper part of the soil usually between 0cm- 10cm depth range in a relatively disturbed soil. [19] reported that soil microarthropods occurred mostly at 10cm and below depths in an undisturbed soil in the tropical rainforest. Furthermore, the undisturbed habitat recorded more species than the petroleum-oil polluted habitats. Multrazine and Glyphosate are herbicides commonly used by farmers in the Southern Nigeria. Herbicides have been reported to influence the abundance and diversity of soil microarthropods when applied to the soil [30] and to this effect, their application in many agro-ecosystems will influence microarthropods distribution. This study investigated the effects of herbicides on soil microarthropods richness and distribution in tropical soils in Nigeria.

2. MATERIALS AND METHODS

The investigation was carried out in 5 months ((August to December 2017), with the application of two herbicides; glyphosate and multrazine to unpolluted soil.

Study Area

The investigation was carried out at the University Park, University of Port Harcourt, situated in the Southern part of Nigeria (6^o19^1N, 6^o36^1E).The prevailing climate is tropical monsoon with bimodal type of rain fall throughout the year. Rain season starts from match to October while dry season starts from November to February. The heaviest precipitation in the city occurs in September with an average of 370mm of rain. Temperature shows little variation throughout the year.

Experimental Design

The study area was divided into four plots measuring 31 x 11m^2 and sub-divided into sub-plots, each measuring 9 x 11m^2, and laid out in a Randomized Complete Block Design (RCBD). The herbicides were prepared into three doses; low, standard and high of the respective herbicides. The doses for glyphosate were low (1.4mμm^2 active ingredient, a.i), standard (2.8ml/m^2 a.i) and high

(5.6ml/m^2 a.i), and for multrazine, it was low (2.1ml/m^2 a.i), standard (4.2ml/m^2 a.i) and high (8.4ml/m^2 a.i). These dosages were treated to the plots and the blocks were well delineated and marked out to ensure non-interference of the treatments (herbicides). The treatments were applied using a small volume hand sprayer with a capacity of 250ml. The control experiment was set up without the treatments. The entire sets up were left to stand for 14 days before soil sampling to ensure that the herbicides actually get into the soil.

a. Collection of Sample

Collection of soil samples was done after 14 days-post treatment and later at intervals of 21 days during the study period. Samples were collected using a bucket-type auger (8.5cm^2 diameter) from soil depth ranges of 0-5cm, 5-10cm, 10-15cm and 15-20cm from both treatments and control plots between the hours of 8 to 10am. During collection, the auger was pushed into the soil and rotated by vertical application in clockwise and anti-clockwise directions at each depth. Each soil samples collected were gently placed in polyethylene bags and transported to Entomology Research Laboratory of the Department of Animal and Environmental Biology, University of Port Harcourt for extraction.

b. Extraction Technique

Mites and Collembolans were extracted using a modified Berlese-Tullgren funnel extractor [9]. Soil samples collected were removed from the polyethylene bags and placed on a fine wire mesh screen at the top of the funnels. The brightness and heat generated from the bulbs stimulates the animals from the upper part and force them to fall into small collection vials containing 70% ethanol and preserved in the laboratory for identification. The description of the funnel and its efficiency has been reported [15]. The extraction process lasted for 7days.

c. Sorting and Identification of extracted microarthropods

The extracted arthropods were placed in a Petri-dish and observed under a stereoscopic microscope. Each specimen was carefully sorted and counted with forceps for identification [22]. Mites and collembolans recoded were categorized into species level according to the criteria proposed by several authors [5, 21, 23, 25, 26 and 33]. Identification was done at the Entomology Research Laboratory of the Department of Animal and Environmental Biology, University of Port Harcourt, Nigeria.

Statistical Analysis

The data obtained were subjected to analysis of variance (ANOVA) using SAS 20 at 95% level of significance. Treatment means were subjected to the New Duncan's Multiple Range Test (NDMR) at 0.05 error limit.

3. RESULTS AND DISCUSSION

Effects of Herbicides on species richness

The result of the study shows that a total of 14 specimens comprising 8 species for Cryptostigmata, 3 species each for Mesostigmata and 3 Collembola were collected (Table1). The effect of multrazine and Glyphosate herbicides was non-appreciable on three microarthropod species; *Galumna* sp; *Scheloribates yorubaensis, Bicrythermannia nigeriana* as they occur commonly in all the three concentrations of the herbicides and the control (Table 1). Out of 14 species that were collected, eleven representing 73.3% occurred commonly at the control and low concentrations of multrazine and glyphosate treated plots (Table 1). The effect of the herbicides was high at standard and high concentrations of multrazine treated plots, as 7 species that occurred at standard and high concentrations of glyphosate treated soils were absent at multrazine-treated soils (Table 1). They include *Mixacarus sp*., *Belbidae -1* sp., *Atropacarus sp*., *Mulierculia sp*., *Parasitid*e sp, and *Uropodidae* sp. The effects of the both herbicides were equally highly severe at standard and high concentrations as 5 species of soil microarthropods; *Paranothrus* sp., *Asca* sp., *Cryptophagus sp*., *Tomocerus sp*., and *Dicyrtomina sp*. were absent, with the first two species occurring at low concentrations of the two herbicides, and the last three completely absent at low concentrations of both herbicides (Table 1).

Table 1. Effect of Multrazine and Glyphosate at Low, Standard and High Concentrations. on microarthropod;s species Richness

Species		Multrazine			Glyphosate		
	Control	Low Con.	Std. Con.	High Con.	Low Con.	Std. Con.	High Con.
Cryptostigmata							
Galumna sp.	+	+	+	+	+	+	+
Scheloribates Yorubaensis.	+	+	+	+	+	+	+
Bicrythermannia nigeriana.	+	+	+	+	+	+	+
Paranothrus sp.	+	+	-	-	+	-	-
Mixacarus sp.	+	+	-	-	+	-	+
Belbidae-*1* sp.	+	+	-	-	+	+	+
Atropacarus sp.	+	+	-	-	+	-	+
Mulierculia sp.	+	+	-	-	+	-	+
Mesostigmata							
Parasitide -1 *sp.*	+	+	-	-	+	+	+
Uropodidae sp.	+	+	-	-	+	+	+

Asca sp.	+	+	-	-	+	-	-
Collembola							
Cryptophagus sp.	+	-	-	-	-	-	-
Tomocerus sp.	+	-	-	-	-	-	-
Dicyrtomina sp.	+	-	-	-	-	-	-

+ = recorded, - = Not found

Effects of Herbicides on Population Distribution of Soil Microarthropods in the Soil Profile

Distribution of soil mites at the control plots showed that a total population of 238 mites occurred at 0-10cm depth range and 120 at 10-20cm depth range. At low concentrations of herbicide-treated plots, 41 mites were collected from multrazine plots and 155 miles from glyphosate plots within 0-10cm depth range. At 10-20cm depth range of the same concentration, 12 mites occurred in multrazine and 36 in glyphosate treated plots (Table 2).

Table 2. Distribution of soil mites at Low Concentrations of Multrazine and Glyphosate-Treated plots

Treatments	Abundance of soil mites at 2 depth ranges		
	0 – 10cm	**10 – 20cm**	**Total**
Control	238	120	358
Multrazine	41	12	53
Glyphosate	155	36	191
Total	434	168	602

At standard concentration of 0-10cm depth range, a total of 30 and 100 soil mites were collected from multrazine and glyphosate treated plots, respectively. The standard concentrations of 10-20cm depth range gave 14 and 71 soil mites, at multrazine and glyphosate treated plots (Table 3)

Table 3. Distribution of soil mites at standard concentrations of Multrazine and Glyphosate- Treated plots

Treatments	Abundance of soil mites at 2 depth ranges		
	0 – 10cm	**10 – 20cm**	**Total**
Control	238	120	358
Multrazine	30	14	54
Glyphosate	100	71	171
Total	368	205	573

At high concentrations, 19 and 27 soil mites were collected from 0-10cm and 10-20cm depth ranges of multrazine-treated plots respectively. Glyphosate-treated plots recorded 102 and 16 miles from 0-10cm and 10-20cm depths respectively at high concentrations (Table 4).

Table 4. Distribution of soil mites at High Concentrations of Multrazine and Glyphosate -Treated plots

Treatments	Abundance of soil mites at 2 depth ranges		
	0 – 10cm	**10 – 20cm**	**Total**
Control	238	120	358
Multrazine	19	27	46
Glyphosate	102	16	118
Total	359	163	522

DISCUSSION

The results of the study show that *Galumna* sp., *Scheloribates yorubaensis,* and *Bicrythermannia nigeriana,* were the most abundant species recorded. They were consistently present in all the treated and control plots, their number tends to be stables as well. The non-appreciable impact of the two tested herbicides on three Oribatid species; *Galumna* sp., *Scheloribates yorubaensis*, and *Bicrythermannia nigeriana,* were due to their ability to withstand stress and resist the herbicidal effects. This agrees with the reports of [2, 4], that such species which withstand stress are categorized as monitor species. The three Oribatid species has been described as good candidate's species for monitoring changes in the ecosystem, [2] to which this study agrees. Species richness varies according to factors such as productivity, spatial heterogenicity, kind of habitat, stages of succession and frequency of distribution [3]. A large edaphic species is found in natural ecosystems (forest, for example) than in systems under intensive cultivation [24, 27]. Several authors have pointed out that the diversity of and interactions between soil dwelling organisms have a major influence on plants on the site, and might account for the higher productivity and quality (higher nutrient content) of plants in some cases [6,12, 28,32 and34]. This study revealed that only three species of collembolans- *Cryptophagus sp. Dicyrtomina sp.,* and *Tomocerus sp.* were recorded in the control plots (Table 1) but completely absent in all the herbicide treated plots. *Crytptophagus* was the dominant species recorded while *Dicyrtomina sp*. was the less abundant. The absence of the Collembloa from the herbicide treated plots may be attributed to the toxic effect of the herbicides on them including negative impacts on their reproductive rates or indirectly on their food source [20]. The study also indicated a vertical migration of soil mites from its usual 0-10cm depth range to its lower layers at standard and high concentrations of multrazine treated plots. This migration is in escape from the toxic effects of the herbicides, which affected the abundance of species, resulting to a shift from 41 species at 0-10cm, 12 species at 10-20cm of multrazine low concentration to 30 species at 0-10cm and 14 species at 10-20cm of standard concentration. The reduction of total soil microarthropods at high concentration of multrazine herbicide from 358 to 46 serve as a good evidence of the severity of the herbicide on abundance of soil microarthropods (Table 4). This agrees with the study that the effects of hydrocarbon oil spill were more pronounced in the uppermost soil layers as there was a reduction of 80% of all soil microarthropods from unpolluted sites, which they attributed to effects that were probably direct (lethal concentration) and / or indirect /adversely affecting food sources, microarthropod reproductive rate or soil quality [19] The effects of multrazine was highly severe on other soil microarthropod species, particularly those seven species that were present at the control and glyphosate treated soils but absent at the standard and high concentrations of multrazine treated soils. The ecological impact of this study is that glyphosate is completely environmentally-friendly while multrazine is averagely friendly. Though, multrazine has a tremendous impact on other species, their non-toxicity to three Oribatid monitor species which usually dominates the agro-ecosystem is an indication of its friendliness to the environment. Consequently, the negative impact of multrazine herbicide on the agro-ecosystem may not be highly severe as *Galumna* sp., *S. yorubaensis,* and *B. nigeriana* which have been reported to dominate the tropical agro-ecosystem [1, 31], still prevails in the treated soils. Similarly there was a statistical difference between the treatments.

4. CONCLUSION

It is apparent that both glyphosate and multrazine herbicides have effect on the richness and distribution of soil microarthropods, though the effect of multrazine was highly severe. Consequently, a reduction in the abundance and vertical migration of the species were observed. Three species, *Galumna, S. yorubanensis* and *B. nigeriana* tolerated the herbicides and could be used as monitor species. Glyphosate is environmentally friendlier than Multrazine herbicides to agro-ecosystems.

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CONFLICT OF INTEREST

Authors have no conflict of interest.

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