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SOIL MICROARTHROPOD- INDICATORS OF EFFECTS OF LIVING MULCHES IN SOLE AND MIXED CROPPING SYSTEMS AT UNIVERSITY PARK FARM, PORT HARCOURT, NIGERIA.

Gbarakoro, T.N. and Umoren, E. I.

[1]Department of Animal and Environmental Biology, University of Port Harcourt, P.M.B. 5323 Choba, Port Harcourt, Nigeria.

ABSTRACT: *This study was undertaken (May – August, 2013) to ascertain the impact of living mulch cover crops on soil microarthropods in sole and mixed cropping systems. Maize (Zea mays), watermelon (Citrullus lanatus), pumpkin (Telfairia occidentalis) and Egusi-melon (Citrullus cococynthis) were cultivated in sole while Maize- watermelon, Maize - Egusi-melon and Maize - pumpkin were cultivated in mixed plots, in a Completely Radomized Design. Soil samples were collected at 21 days interval with an 8.5cm bucket- type soil auger for extraction in modified Berlese-Tullgren funnel. The result showed 12species and 84 individuals (control), 15 and 317 (sole), 18 and 455 (mixed) cropping plots. Living mulch cover crops increases soil microarthropods in the mixed cropping system as there was significant difference (F=0.22, df =1 P>0.05) between the sole and mixed cropping. The average soil moisture within 42days was 30.9 %(mixed), 20.9 %(sole) and 24.4(control). Three species; Parallonothrus nigerensis, Gamisinia and Parasitid were absent in the control and sole but occurred at mixed cropping plots, indicaing that intercropping water- melon or egusi- melon with maize increases the moisture, health of the soil, species richness and abundance of soil microarthropods.*

KEYWORDS: Soil Microarthropods, Living Mulch Cover Crop, Mixed Cropping, Sole Cropping, Moisture Content, Cryptostigmata.

INTRODUCTION

Living mulches are cover crops that cover the ground alive throughout their growing season and that of the main crop. They are distinguished from other cover crops as they are alive while others are killed using herbicides or machines before the main crop is planted. Some living mulches increase populations of natural enemies of desired crop (Hartwig *et al*., 2002), reduces soil erosion and the amount of nitrogen fertilizer required (Hartwig and Ammon, 2002; Miura, 2009). Living mulch cover crops help to control weeds, thereby reducing the herbicide input and also reduce water runoff and soil erosion in maize cropped on slopes (Hall *et al*; 1984).

There are various types of living mulches; Leguminous, graminous and vegetable types. These living mulch cover crops can be grown as one crop variety alone in a farm referred to as sole cropping or grown as two or more crops simultaneously on the same piece of land, known as mixed cropping. Soil microarthropods are small, minute organisms whose body width is between 100um-2mm and occur in the litter, soil-litter interphase and topsoil to the depth of 10cm, and they include mesofauna which are mainly mites and collembolans that perform the following functions: Facilitation and Regulation of microbial population and activities including decomposition and mineralization of dead organic matter (Badejo, 2004); Participation in nutrient cycling and conservation (Moldenke, 2000); Maintenance of soil

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structure and fertility (Coleman and Crossley, 1996). They are also indicators of petroleum oil pollution in the environment (Okiwelu *et al*; 2011).

LITERATURE AND THEORETICAL UNDERPINNING

The effect of living mulches on soil (below ground) organisms have not received much attention though increased biomass of microbes and earthworms and a large population of Collembola on the soil surface were recorded in grass white clover systems in Switzerland (Jággi *et al*., 1995). White clover (*Trifolium repens* L.) when cropped as a living mulch with wheat (*Triticum aestivum* L.) in a mixed cropping practice in Ireland and Britain increased the biomass of microbes and earthworms (Lumbricidae) than conventional mono-cropping (Schmidt *et al*., 2001). Populations of mites were consistently and significantly larger in plots with white clover living mulch than plots without living mulch (Nakamoto and Tsukamoto, 2006).

Daily temperature fluctuation in the soil affects the survival and reproduction ability of Oribatids (Uvarov, 2003). PH affects the abundance and vertical distribution of soil microarthropods in the soil profile (Rusek and Marshal, 2000).

Both living mulch cover crops and soil microarthropods play key roles in the soil as such the effects of the former must affect the latter. Secondly, soil microarthropods are indicators of changes in the environment, and thus could detect changes in the soil caused by living mulch cover crops. Thirdly, agricultural practices; pesticides and herbicides inputs have been reported to reduce soil microarthropods (Gbarakoro and Zabbey, 2013).

This present study is conducted to: (a) ascertain soil microarthropods that indicate effects of living mulch cover crops in both sole and mixed cropping systems (b) determine the relationship between soil microarthropods' abundance, and edaphic factors in both sole and mixed cropping systems.

METHODOLOGY

Experimental Design and Sampling:

The total area for the study was 108m^2 and divided into 8 plots measuring 4.5m by 3m each. The plots were separated from each other by 1m apart. The plots were planted randomly with sole cropping of maize (*Zea mays*), water melon (*Citrullus sp*), pumpkin (*Telfaria occidentalis*), and Egusi-melon (*Citrullus coco-cynthis*). The mixed cropping were maize and water melon, maize and Egusi-melon, maize and pumpkin. The control was a one year uncultivated farm bush where crops has been harvested. The entire farms were replicated four times in a completely randomized design.

Soil samples were collected with an 8.5m diameter bucket auger three weeks after planting of living mulch cover crops.

The samples were collected from two depth ranges; 0-7.5cm and 7.5-15.0cm from all the plots including the control. The samples were collected in accordance with the description by Gbarakoro *et al*., (2010).

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The collected soil samples were taken to the laboratory for analyses. The laboratory analyses consisted of a 3-stage process (extraction, sorting and identification). The modified Bukard model of the Berlese-Tullgren funnel was used for extraction. The extractor complex consisted of two rows of 8 units, each enclosed in an airtight aluminum cabinet with vertically sliding doors to ensure faster extraction. Descriptions of the extractor unit and extraction procedure are documented (Badejo, 1990, 1995; Badejo and Olaifa, 1997). Sorting and identification was undertaken under a compound microscope at the Entomology Research Laboratory, Department of Animal and Environmental Biology, University of Port Harcourt. The method applied for sorting was that described by Gbarakoro *et al*., (2010). Identification keys {Krantz, 1978; Norton 1990; Woolley, 1990} and type specimens were used.

The identified soil microarthropods were counted and recorded for 21, 42 and 63 days post cultivation.

Measurement of Edaphic Factors:

Temperature readings were taken between mercury – in – glass thermometer. This was carried out by inserting the thermometer into the soil to a depth of 10cm for 5minutes before taking the reading in degree Celsius (^{0}c).

Soil samples were collected from 0-10cm depth from each plot on collection days. 20g and 50g of soil was weighed using an OHAUS portable scale scout 11 electrical weighing balance for soil P^H and soil moisture (relative humidity) respectively.

For soil P^H, soil sample was sundried and put in a 50ml beaker and 20ml of distilled water added and allowed to stand for 30minutes. The mixture was stirred occasionally with a glass rod. The electrode of each Equip-Tronics digital P^H meter (model EQ-610) was then inserted into the solution from each plot and the P^H readings recorded.

For relative humidity, the samples were wrapped in Tower foil paper, labelled and placed in B and T Laboratory thermal Equipment (Oxen) for 24hrs. Moisture was then calculated using the formula;

$$\text{Soil moisture content (\%)} = \frac{\text{Loss in Weight} \times 100}{\text{Initial Weight}}$$

RESULTS

Species richness and abundance:

At the end of the study, a total of 18 species and an abundance of 856 individuals of soil microarthropods were collected from the control, sole cropping and mixed cropping living mulch plots or habitats. A total of 12 species and 84 individuals were recorded from the control habitat, an additional 3 species to those obtained in the control totaling 15 species and an abundance of 317 from sole cropping living mulch habitat, and 18 species with 455 individuals from mixed cropping habitat (Tables 1 & 2) were recorded.

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Table 1: Soil Microarthropods in the three habitats during the study

S/N	Soil Microarthropods	Control	Sole	Mixed
1.	*Annecticarus sp*	+	+	+
2.	*A. magus*	-	+	+
3.	*Cephalid sp*	-	+	+
4.	*Galumna nigeriensis*	+	+	+
5.	*Mixacarus sp*	+	+	+
6.	*Nothrus ifeansis*	+	+	+
7.	*Nothrus incavatus*	+	+	+
8.	*Oppia sp*	-	+	+
9.	*P. nigeriensis*	-	-	+
10.	*S. yorubaensis*	+	+	+
11.	*Scheloribates sp*	+	+	+
12.	*Gamisina sp*	-	-	+
13.	*Macrochelid sp*	+	+	+
14.	*Parasitid sp*	-	-	+
15.	*Rhodacarus sp*	+	+	+
16.	*Uropoda sp*	+	+	+
17.	*Hypogastura sp*	+	+	+
18.	*Paronella sp*	+	+	+

Table 2: Species abundance at the cover crop habitat

Treatment	Cryptostigmata	Mesostigmata	Collembola	Total
Control	54	16	14	84
Sole Cropping	236	21	60	317
Mixed Cropping	250	135	70	455
Total	540	172	144	856

Among the three orders of soil microarthropods recorded in this study, eleven species belong to Cryptostigmata that recorded the highest number of individuals (540), followed by 5 species that belong to Mesostigmata with 172 individuals and 2 species of Collembola with 144 individuals (Table 2 & 3). The distribution of species along the three orders of soil microarthropods in the respective habitats were; Mixed cropping habitat; 11 (Cryptostigmata), 5 (Mesostigmata) 2 (Collembola), sole cropping habitat; 10 (Cryptostigmata) 3 (Mesostigmata), 2 (Collembola) and control habitat; 7 (Cryptostigmata), 3 (Mesotigmata) and 2 (Collembola).

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Table 3: Species richness of Soil Microarthropod in the cover crop habitat

CRYPTOSTIGMATA (Oribatida)	*MESOSTIGMATA (Gamisida)*	*COLLEMBOLA*
Archegozettes magnus	*Gamisina sp*	*Hypogastura sp*
Annecticarus sp	*Macrochelid sp*	*Paronella sp*
Cephalid sp	*Parasitid sp*	
Galumna sp	*Rhodacarus sp*	
Mixacarus sp	*Uropoda sp*	
Nothrus ifeansis		
Nothrus incavatus		
Oppia sp		
Parallonothrus nigenensis		
Scheloribates yorubaensis		
Scheloribates sp		

The distribution of soil microarthropods and abundance in the three habitats within the period of post cultivation study was recorded. In all the plots, there was a decrease in the number of species as the days of post cultivation increased (Table 4). The highest number of species was recorded in the mixed cropping plots in 21 days post cultivation and the least in 63 days in the control plots (Table 4). Mixed cropping plots recorded a progressive abundance within 21 and 42 days post cultivation. The control recorded the least abundance within this period (21 and 42 days).

Table 4: Species richness during the study period

Treatment	21days	42days	63days
Control	12	7	5
Sole Cropping	12	11	10
Mixed Cropping	18	13	11

Among the orders of soil microarthropods, Cryptotistigmata recorded the highest number of soil microarthropods (540) followed by Mesostigmata (172) and Collembola (144) (Table 2). The highest abundance (419) occurred within 42 days followed by 21 days (290) and least (147) within 63 days (Table 5). Within 21 and 42 days the least number of Cryptotistigmata and Mesostigmata was recorded from the control plots.

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Table 5: Species abundance at the cover crop habitat during the period of study

Treatment	21days	42days	63days	Total
Control	37	31	16	84
Sole Cropping	82	164	71	317
Mixed Cropping	171	224	60	455
Total	290	419	147	856

Table 6: Vertical distribution of soil microarthropods in each crop

Treatment	0 -7.5cm	7.5 – 15cm	Total
Maize	25	23	48
Water melon	25	65	98
Pumpkin	55	29	84
Egusi-melon	71	84	155
Maize and Egusi melon	64	88	152
Maize and Water-melon	85	62	147
Maize and pumpkin	53	43	96
Control	64	20	84
Total	442	414	856

Egusi-melon and water-melon among sole cropping habitat recorded the highest number of soil microarthropods with 155 and 98 individuals respectively. In the mixed cropping habitat; maize-egusi melon and maize-water melon recorded the highest number of individuals of soil microarthropods with 152 and 147 respectively. The least abundance in sole cropping was observed in maize plots because maize could not cover the soil as Egusi-melon did. While in mixed cropping, the least abundance was recorded in maize-pumpkin plots (Table 6). The average soil moisture content within 42 days in mixed cropping habitat was 30.9% as against 20.9% and 24.4% in sole cropping and control habitats respectively.

Indicators of Soil Health Status:

Out of the 18 species recorded in this study, three species; *Parallonothrus nigeriensis*, *Gamisina and Parasitid* spp were absent in both the control and sole cropping habitats but occurred at mixed cropping habitat, similarly, three other species; *Archegozettes magnus*, *Cephalid* sp and *Oppia* sp that were absent in the control habitat occurred at the sole cropping

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habitat (Table 1). In fact, five species; *Oppia*, *P. nigeriensis*, *Scheloribates yorubaensis*, *Gamisina*, and *Parasitid* were absent in sole cropping habitat at 21 days post cultivation but occurred at mixed cropping habitat within the same 21 days period.

DISCUSSION

Mixed cropping living mulch habitat was richer in species and abundance of soil microarthropods than sole cropping living mulch habitat. Living mulches actually increased the number of species and abundance especially as the number recorded was higher than those from the control plots. The high abundance of some species of soil microarthropods; *Nothrus* sp, *Schelorilates* sp, *Mixacarus* sp, *Galumna* sp, *Rhodacarus* sp and *Paronella* sp is an indication of effects of living mulch cover crops. These species recorded a total of 594 individuals out of 856, which were distributed as 66,248, and 257 at the control, sole and mixed cropping habitats respectively. Living mulch cover crops increases soil microarthropods in the mixed cropping habitat than sole cropping habitat especially as there was significant difference ($F = 0.22$; $df = 1$ $P > 0.05$) between the sole and mixed cropping in this study.

The reduction in species distribution and increase in abundance as the days of post cultivation increased is due partly to drying of the leaves of the living mulch cover crops whose canopy could no longer cover the ground as the crops aged. The non-covering of the ground allows the heat of sunlight on the ground which affects the species richness of the soil microarthropods. The increase in abundance within the period is caused by the effect of the living mulch which improves the soil moisture content making it adequate to allow such an increase. This improvement is probably referred to as organic materials released from the living roots of living mulches which help preserve soil organisms and enhance their ecosystem function (Schmidt *et al.*, 2001. This agrees with the report that soil moisture condition may have been improved by the living mulches which caused increase in living mulch mixed cropping (Nakomoto and Tsukamoto, 2006). The improvement of the soil moisture was more in the mixed cropping plots. This also agrees with the report that the population of mites increased more rapidly, reaching a level of 3 to 5 times that in the control (Nakomoto and Tsukamoto, 2006).

Ground cover by living mulch was responsible for the higher abundance of soil microarthropods within 42 days post cultivation as it creates a condusive habitat which reduced water loss through the soil surface.

The adequate moisture content in mixed cropping plots caused by living mulch improves the health status of the habitat, and caused increase in soil microarthropods abundance.

The high abundance of soil microarthropods in Egusi-melon plots is also caused by the leaf canopy of Egusi-melon which covers the ground more than maize and pumpkin. Furthermore, Egusi-melon improves the health status of soil as it compete less for nitrogen with maize than pumpkin, giving storage of nitrogen that enrich the soil. This agrees with the report that leguminous living mulches compete less with maize for nitrogen than do graineous living mulches and results in greater density of soil organisms (Feil et al; 1997).

Another area where the effect of living mulch is shown in this study is the absence of some species of soil microarthropods in one habitat and their presence in another habitat at the same period.

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These absented species are indicator species and that their absence and presence in the control and sole cropping habitats respectively is an indication that the latter habitat has been fairly improved by living mulch cover crops more than the former habitat. Similarly, the absence of three species in the sole cropping and control habitats is an indication that the health status of their respective soils is not good enough for the growth of all species of soil microarthropods. However, their presence in mixed cropping habitat indicates that the health status of the soil is much better than that of the control and sole cropping. It also indicates that mixed cropping living mulch improves the health of the soil within 21 days cultivation than sole cropping living mulch within the same frame of time.

The highest abundance of species in all the habitats occurred within 42 days post cultivation. During this period, the average moisture content of the soil in the habitats were; 24.4 %(control), 21 %(sole cropping), and 31% (mixed cropping). High moisture content caused by living mulch cover crops is responsible for high abundance of soil microarthropods recorded in this study. There is a relationship between abundance and moisture content of the soil; the higher the moisture, the more the abundance of soil micro arthropods. This agree with the report that higher moisture results in greater density (Lindo and Winchester, 2006; Melamud et al., 2007).In general, more species were found at 0-7.5cm depth than at 7.5-15.0cm depth in all habitats except for water melon and egusi-melon in sole cropping and maize-egusi melon in mixed cropping, where there was more species at 7.5-15.0cm depth. Insects deep in soil may be relatively protected from large changes in air temperature and relative humidity (Curry, 1994) as high moisture content of soil can mitigate heat penetration and protect soil fauna. This may be the case with soil microarthropods and egusi-melon and water-melon in this present study.

Implications to Research and Practice

The study showed that intercropping water-melon or Egusi-melon with maize helps increasing the moisture content of the soil through canopies of their leaves which cover and shade the ground from sun- and temperature- changes, and contribute to the health status of the soil by releasing organic materials from their living roots which help preserve soil microarthropods and conservation of nitrogen in the soil as they compete less for nitrogen with maize. These results in the improvement of the soil health which lead to increase in soil microarthropods and better yield of crops.

CONCLUSION

Soil microarthropods were abundant in mixed cropping than sole cropping systems. Soil microarthropods were observed to be indicators of health status of soil ecosystem in mixed and sole cropping systems, as shown by variation in species diversity and abundance in the three habitats, absence of certain species at a particular habitat and their presence in another habitat within the same time frame. The absence of some species of mites is an indication of poor health status of soil ecosystem, while the presence of few species indicates fairly improved and improved health status of soil ecosystem.

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Future Research

The impact of intercropping water-melon with maize on the relationship of the abundance of soil microarthropods and concentration of soil nutrients.

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