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EFFECTS OF SOIL AMENDMENT WITH POULTRY LITTER ON SOIL-DWELLING MITES (ORIBATIDA) AND SPRINGTAILS (COLLEMBOLA) IN LIYETU, ONDO, SOUTHWESTERN NIGERIA.

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ABSTRACT

The effects of poultry litter application on soil microarthropods were investigated on a 319 m^2 plot of land in the Agricultural Farm of the Wesley University of Science and Technology in Liyetu, Ondo, in southwestern Nigeria. In 2010, sampling of soil microarthropods was carried out biweekly for 4 months in the plot before incorporating poultry litter. In 2011, the plot was divided into 10 equal subplots separated from one another by a 1m strip. Dry poultry litter (20kg) was introduced and mixed thoroughly with the surface soil (0-7.5cm) of 5 alternate subplots while the untreated subplots served as control. Four soil samples were taken randomly and monthly thereafter to monitor the microarthropod populations in the treated and control subplots on a temporal scale. Altogether, 17 species of oribatid mites, four families of gamasid mites, three families of actinedid mites and 10 genera of springtails were identified in the experimental plots before and after the application of poultry litter. The juveniles of detritivorous, coprophagous and mycophagous mites and springtails increased in numbers in response to poultry litter application. This increase led to an increase in their adult populations the following year as observed in the post-treatment results. The populations of the predatory gamasid and actinedid mites did not respond in any way to poultry litter application. These findings confirm that the beneficial effect of soil amendment with poultry litter on detritivorous, coprophagous and mycophagous soil dwelling mites and springtails may not be noticeable until the year following application.

Key words: detritivores, mites, poultry litter, springtails, relative abundance.

INTRODUCTION

Due to increasing population growth and the consequent pressure on agricultural soils, decline in soil fertility became imminent. Efforts to boost soil fertility without any significant adverse effects on the environment and the organisms living in it became intensified by researchers in agric-related fields (Tian *et al.*, 1997). Consequently, ecosystem management has embraced the use of pesticides and fertilizers derived from plants, animal wastes and minerals (Kaur and Reddy, 2014).

The use of bio-waste has been directly linked with improved soil health status as the organic matter content of the soil increases. Organic matter provides glue-like substances that act to stick individual particles together to form stable aggregates and good soil structures (Sharma and Bali, 1998). It has also been reported that soil organic matter has a positive effect on soil structure, tilth, water-holding capacity, aeration, pH buffering, cation exchange capacity, and microbial activity (Bauer and Black, 1992; Tahboub *et al.*, 2008). Poultry litter has an impact on soil pH and liming due to varying amounts of calcium carbonate in poultry feed (Van Devender *et al*., 2002). Populations of microarthropods in the soil and litter layer are normally supported by organic debris of all kinds as they comminute and fragment litter directly through their feeding activities. Walter *et al.* (1989) reported that the rehabilitation of degraded rangeland requires rebuilding the soil, including soil biota while Minor and Norton (2008) in a study of the effects of biosolids (lime-stabilized solid sludge), chicken manure compost, urea fertilizer and black plastic mulch on the assemblage of mites (Acari: Oribatida and Mesostigmata) in a short-rotation willow planting in Central New York concluded that composted chicken manure supported abundance and diverse population of these two groups of Oribatida..

In Nigeria, Alabadan *et al.* (2009) in their study on the effect of different poultry wastes on the physical, chemical and biological properties of soil posited that there is a direct relationship between the biological properties of the soil and the amount of poultry waste applied. The densities and activities of soil mites were found to increase in organic cultivation in an ultisol in southeast Brazil, although the community structure and recruitment period of oribatid mites were altered after a general initial reduction in their populations (Badejo *et al*., 2004).

Atere and Olayinka (2012) reported that soybean agronomic parameters and yield parameters were significantly increased by soil treatment with water hyacinth compost and that the soil pH, organic carbon, available P and exchangeable cations (Ca, K and Mg) were also increased. So also, Paul *et al.*, (2017) reported that poultry manure was sufficient to encourage the capability of eggplant to produce high total yield and enhanced the fruit characters which led to increased vegetative growth and consequently favoured carbohydrate build up which resulted in more plant growth characters and yield components of the eggplant. As a result, it was suggested that the rate of poultry manure be increased for increased eggplant production.

In this study, the effect of dry poultry litter on the densities of different taxonomic groups of soil mites and springtails in a secondary regrowth forest in Ondo, southwest Nigeria was investigated so as to add to the scanty information on the populations of microarthropods in relation to organic manure in the tropical rainforest zone.

MATERIALS AND METHODS

Study site

This study was carried out at the Agricultural Farm of the Wesley University of Science and Technology, Liyetu (7^{o} 15′ N, 5^{o} 00′ E), Ondo, Ondo State, Nigeria. Ondo is located within the tropical rainforest zone; so the climate is typical of that of the tropics which is relatively hot, humid with distinct dry and rainy seasons. In this agroecological zone, the usual rainfall pattern is bimodal where the rainy season is from April to October with August breaks. The experimental site is about 50 meters away from the University Poultry Farm, which housed about 8,000 chickens (layers). Verbal interaction with villagers near the experimental site revealed that the area had been abandoned for about 15 years without farming and other human activities. The flora components of the study site are dominated by trees, shrubs, climbers, liana, herbs, and few ferns, bryophytes and orchids.

Plot design, experimentation and sampling techniques

In May 2010, a 29 m × 11 m plot was marked out from the study site for pre-experimental sampling. With the aid of a standard bucket auger, whose diameter is 7.5 cm and bucket height of 12.5 cm, eight soil samples were randomly collected biweekly from this plot from May to August, 2010. The soil samples were taken to the laboratory immediately after collection and a modified Berlese-Tullgren funnel extractor was used to extract microarthropods from them using light and heat as repellents (Badejo, 1982). The extraction lasted for seven days (Lasebikan, 1974) and the microarthropods extracted were preserved in 70% ethanol. Soil samples were also taken for analysis of physicochemical properties using the methods employed by Atere and Olayinka (2012).

In April 2011, the plot was cleared and marked into a 2 × 5 grid of 5 m × 5 m sub-plots with 1 m border strip of land separating each sub-plot. Fresh poultry droppings were collected from the Wesley University Poultry Farm nearby, sun-dried and 20 kg of the dry poultry litter was incorporated into the surface soil (0 – 7.5 cm) of each treatment subplot by mixing it thoroughly with the surface soil where the activities of soil microarthropods in the zone have been reported to be most significant (Badejo, 1979; Osewa, 1988).

Five of the ten sub-plots received poultry litter treatment while the remaining five served as control. The treatment and control sub-plots were alternated in such a way that no two treatment plots were contiguous with each other.

A month after amendment of the treatment sub-plots with dry poultry litter, four soil samples were collected randomly biweekly from each of the treatment and control sub-plots from May to August 2011. Due to the fact that soil microarthropods respond slowly to organic amendments, a second round of post-treatment samples was also collected from May to August 2012.

After extraction on each sampling occasion in each year, the mites and springtails were separated from the extracted microarthropods, enumerated and sorted into different taxonomic groups. Identification of the different taxonomic groups of mites was carried out to the generic or species level where possible using the keys provided by Norton (1990) and Balogh and Balogh (1992), as well as comparison with illustrations of type specimens of newly described species in Badejo *et al.* (2001a, 2001b, 2002a, 2002b and 2002c). The springtails were also identified using the keys and illustrations provided in Lasebikan *et al.* (1980), Bellinger *et al.* (1996), Deharveng (2004), and Christiansen and Nascimbene (2006).

Measurement of environmental factors

On each sampling occasion, four mercury-in-glass thermometers were inserted randomly into the soil to a depth of about 3 cm around the sampling spots, and left in place for twenty minutes before temperature readings were taken *in situ*. Four soil samples were also collected randomly from each plot for moisture content determination using the gravimetric oven-drying technique. Data on the mean annual rainfall were collected from the meteorological station in Ondo, which is about 20 km away from the site of study.

Statistical Analysis

Mean and standard error of mean were calculated for each taxonomic group. Student's t-test was carried out on the mean values to determine significant difference between the data obtained from the treated and control subplots using the IBM SPSS 16 full version for Windows.

RESULTS

The physicochemical parameters of soil samples collected from the site before amendment with poultry litter are presented in Table 1. The soil was slightly acidic (pH 5.9-6.4) with relatively low organic matter content. The organic matter content of the surface 7.5 cm of the soil falls between 0.27 and 1.81%. Low pH suggests acidity and consequently poor nutrient relations (Swift and Woomer, 1993).

The soil is classified as sandy clay loam based on the combination of percentage of size fractions (50% sand, 35% clay, and 15% silt) using USDA standard soil textural triangle. The soil's exchangeable cations was relatively high with Calcium (Ca) and Magnesium (Mg), while this was low with Sodium (Na) and Potassium (K) (Table 1).

Table 1. Physicochemical properties of the soil in experimental plots before amendment with poultry litter.

Subplot		PARTICLE SIZE (%)			ORGANIC	EXGHANGEABLE		CATIONS	
	p($CaCl_2$)	SAND	SILT	CLAY	MATTER (%)	Na^+	K^+	Ca^{2+}	Mg^{2+}
1	6.1	66	11	23	1.21	0.14	0.13	3.2	1.0
2	5.9	50	15	35	0.268	0.13	0.08	0.12	1.8
3	5.9	40	11	49	0.470	0.09	0.12	0.4	1.4
4	6.0	50	19	31	0.738	0.08	0.05	0.3	4.6
5	6.0	40	20	45	1.811	0.07	0.04	0.2	1.4

Table 2. Total monthly rainfall, mean values for soil temperature and moisture content of the sampling plots.

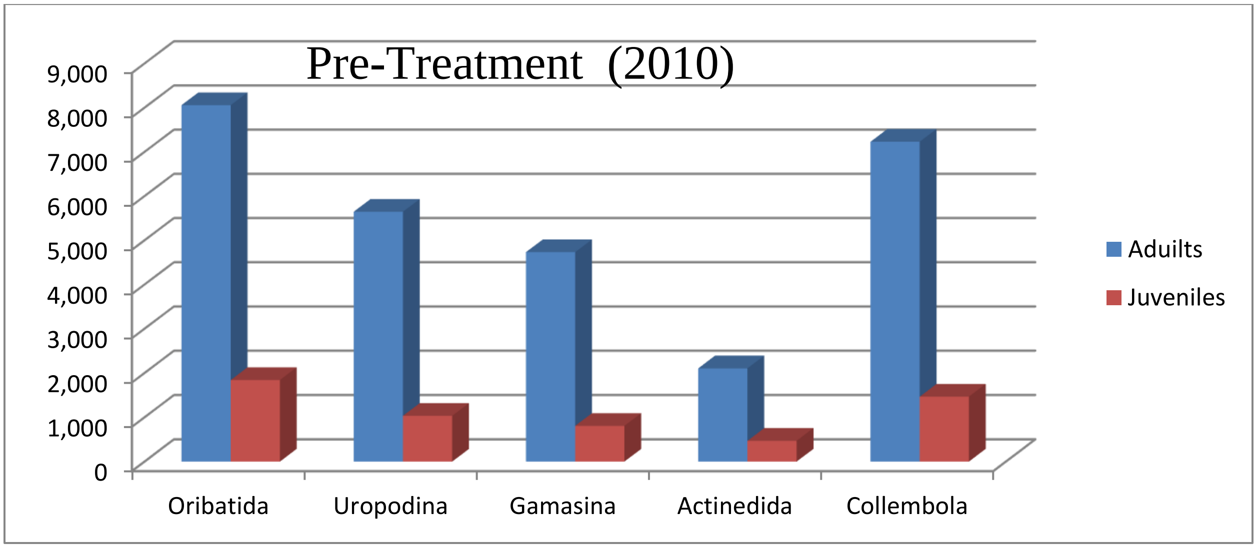
Environmental Factors	Year	April	May	June	July	August
Soil Temperature (^oC)	2010	24.89	24.57	24.55	24.41	23.85
	2011	25.01	24.86	24.41	24.02	24.63
	2012	24.76	24.17	24.01	24.50	24.11
Soil Moisture Content (%)	2010	13.63	16.17	17.75	16.88	18.63
	2011	18.39	18.92	20.05	20.11	19.64
	2012	17.56	19.89	21.10	21.50	20.88
Total Monthly rainfall (mm)	2010	109.8	147.1	213.4	177.4	454.9
	2011	73.6	189.9	223.8	364.4	180.5
	2012	92.8	153.0	241.3	234.7	233.4

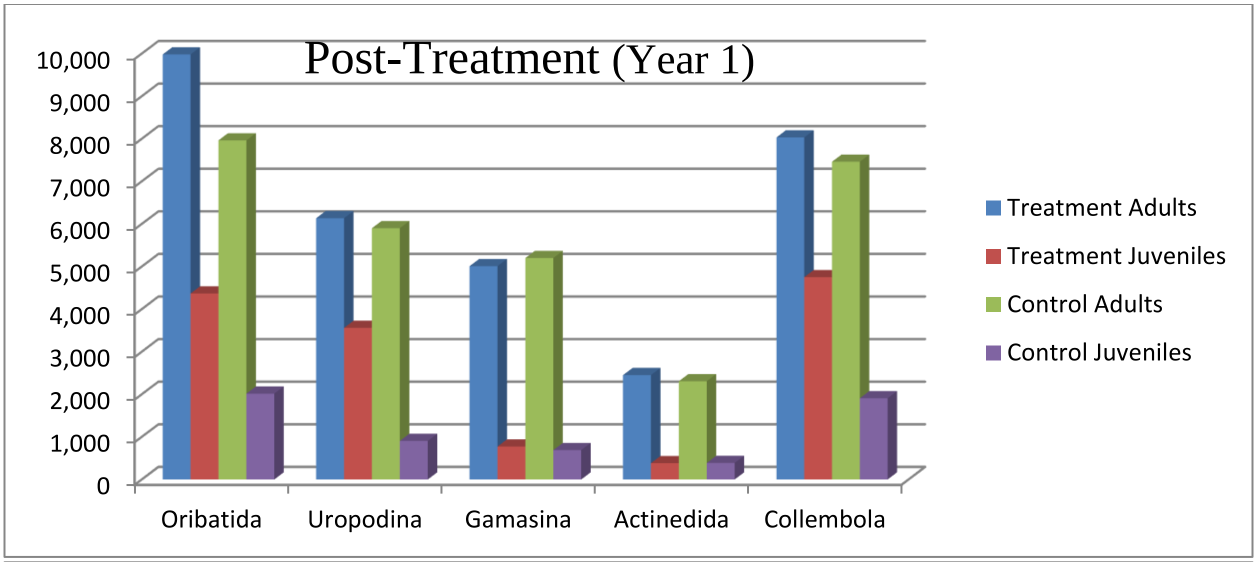
Total precipitation, soil temperature and moisture content of experimental plots are presented in Table 2. Data for the monthly rainfall in Ondo during the period of study reveals that the site received heavy rainfall during the sampling period. The highest precipitation (454.9 mm and 364.4 mm) occurred in August and July of 2010 and

2011, respectively. In April of each year when percentage moisture content of the soil was relatively lower than in other months, soil temperatures were relatively higher as a result of the relatively lower rainfall in this month when compared with other months. Correlations between soil moisture content on the one hand and soil temperature on the other hand, with soil microarthropod numbers have already been established by Badejo and Lasebikan (1988); Badejo, (1990) and Badejo and Van Straalen (1993).

Fig 1 reveals the relative abundance of the mites and springtails in the experimental plots, before, during and after soil amendment with poultry litter. It also reveals the proportion of juveniles to adults in the study site. Before amendment, adults far outnumbered juveniles by a magnitude of four to five. After amendment, the proportions changed as juveniles were up to or more than half of the adult oribatid and uropodid mites as well as springtails in the treatment plots. The situation remained the same in the control plots. In the post-treatment period, the adult oribatid and uropodid mites had increased tremendously in numbers such that they were now more than the juveniles by a magnitude of up to six in oribatid and uropodid mites. The adults of gamasina and actinedid mites appeared not to be affected by the treatment both in magnitude and relative proportions of the juveniles.

Table 3 reveals that during the entire period of study, 17 genera of oribatid mites were recorded out of which only one of them could not be identified beyond family level. Gamasina was considered as a group but there were six families of uropodid mites, three families of actinedid mites and ten genera of springtails. The Student's t-test revealed taxonomic groups whose densities were different in the experimental plots from the control plots in the two post-treatment years.





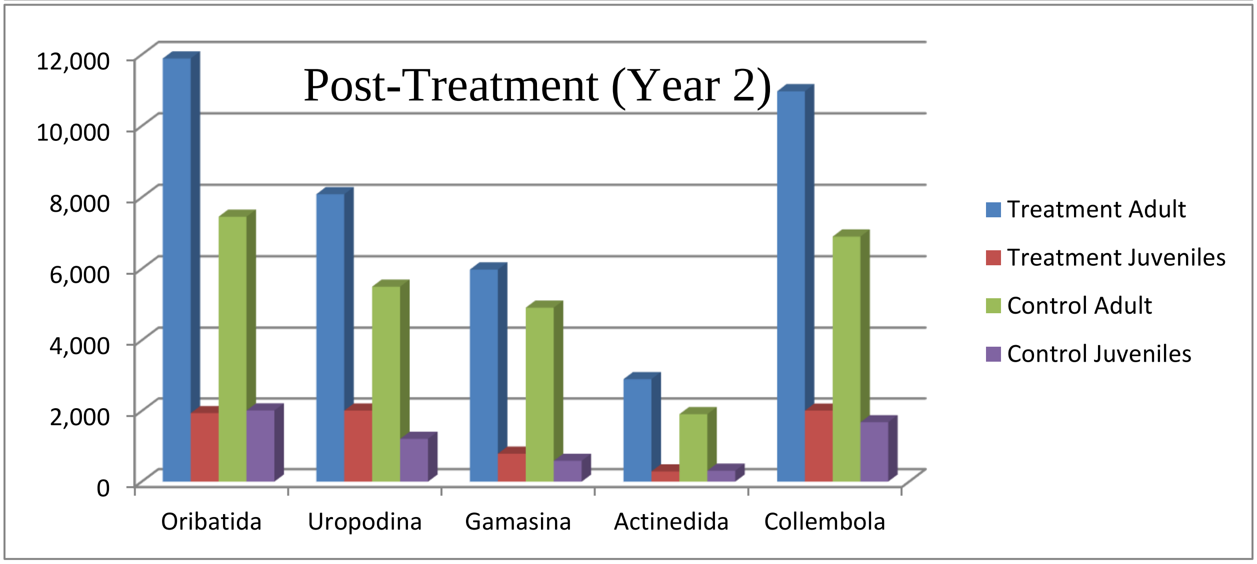


Fig 1. Relative abundance of mites and springtails (No per m^2) pre- and post-treatment.

Poultry litter did not significantly lead to an increase in the adult populations of oribatid and uropodid mites as well as springtails immediately after treatment but there was an increase in the numbers of their juveniles. One year after application of poultry litter, virtually all the adult populations of oribatid and uropodid mites significantly increased in numbers except gamasina and actinedida.

DISCUSSION

The mites and springtails are the most abundant soil microarthropods in forests and agroecosystems in the study area (Lasebikan, 1974; Badejo, 1982; Tian *et al*., 1997). When poultry litter was introduced to the soil of the experimental plots in 2011, the adult mites and springtails did not increase tremendously in densities, rather, their juveniles did. These juveniles are those of the detritivorous oribatid and coprophagous uropodid mites on the one hand and detritivorous and mycophagous springtails on the other hand. These primary decomposers must have responded to soil amendment with poultry litter by increasing their reproductive activities. This suggests that there is a positive relationship between food availability in the soil and reproductive ability of detritivorous mites and springtails. It is not surprising however that the predatory gamasid and actinedid mites, showed no response to the introduction of poultry litter because they do not feed on organic matter. The organic fraction which falls between the range of low and medium (Adepetu, 1990), is extremely important because it is a good source of essential nutrients, contributes to good soil structure, has a high water holding capacity and serves as a buffer against changes in pH. However, populations of these predatory mites may increase in later years as upsurge in the populations of their preys continue, thus, indirectly benefitting from the effects of poultry litter application. This supports the findings of Minor and Norton (2008) that the predatory Gamasida which initially responded differently from the detritivorous Oribatida when they investigated effects of soil amendments on the assemblage of mites in a short-rotation willow planting in Central New York. They concluded that composted chicken manure eventually supported abundance and diverse population of both groups.

Table 3. Mean values (± S.E.) of mites and springtails sampled in the experimental plots during the sampling period

Taxonomic Groups	Pre-experimental Period (2010)	Experimental Period (2011)		Post-experimental Period (2012)	
ORIBATIDA		**Treatment**	**Control**	**Treatment**	**Control**
Atropacarus ifeensis	3.49 ± 0.37	2.84 ± 0.33	3.40 ± 0.43	3.23 ± 0.43	3.65 ± 0.39
Mesoplophora ifeana	2.80 ± 0.36	3.81 ± 0.32	3.50 ± 0.30	6.18 ± 0.43	2.35 ± 0.47*
Annectacarus sp.	4.85 ± 0.42	5.46 ± 0.42	4.64 ± 0.44	8.20 ± 0.48	4.73 ± 0.57*
Mixacarus sp.	2.77 ± 0.38	3.45 ± 0.48	3.10 ± 0.46	7.30 ± 0.37	3.38 ± 0.48*
Haplozetes sp.	3.95 ± 0.84	4.39 ± 0.37	3.79 ± 0.41	8.68 ± 0.59	3.29 ± 0.46*
Scheloribates mochlosimilaris	6.52 ± 0.40	6.31 ± 0.35	5.14 ± 0.47	7.63 ± 0.67	4.30 ± 0.34*
Scheloribates yorubaensis	6.08 ± 0.33	6.06 ± 0.29	5.58 ± 0.42	7.45 ± 0.60	4.18 ± 0.30*
Bicyrthermania ifeana	5.96 ± 0.44	5.81 ± 0.45	5.98 ± 0.44	8.25 ± 0.64	3.50 ± 0.45*
Pergalumna sp.	2.80 ± 0.41	2.49 ± 0.37	2.84 ± 0.54	2.98 ± 0.44	2.28 ± 0.48
Galumnella sp.	4.22 ± 0.35	3.95 ± 0.28	4.25 ± 0.43	3.36 ± 0.40	3.73 ± 0.43
Teleiolides sp.	2.64 ± 0.40	3.14 ± 0.40	2.83 ± 0.36	3.75 ± 0.34	3.68 ± 0.48
Belba sp.	3.32 ± 0.40	3.54 ± 0.36	3.60 ± 0.37	6.88 ± 0.35	3.10 ± 0.51*
Machadobelba sp.	3.36 ± 0.41	3.38 ± 0.37	3.26 ± 0.52	8.10 ± 0.55	3.45 ± 0.47*
Protoribates ifensis	5.50 ± 0.45	5.10 ± 0.41	4.56 ± 0.36	8.05 ± 0.39	2.60 ± 0.34*
Oppia sp.	3.59 ± 0.47	2.76 ± 0.39	3.65 ± 0.53	3.05 ± 0.34	3.58 ± 0.44
Dolichemereus sp.	2.22 ± 0.37	2.13 ± 0.29	3.38 ± 0.53	3.18 ± 0.30	3.70 ± 0.42
Otocepheidae	2.85 ± 0.34	2.99 ± 0.30	2.38 ± 0.47	6.88 ± 0.38	3.18 ± 0.46*
Juveniles	3.96 ± 0.43	8.21 ± 0.39	3.73 ±0.37*	6.30 ± 0.44	3.78 ± 0.46*
GAMASIDA					
Gamasina	5.58 ± 0.44	5.65 ± 0.39	5.38 ± 0.57	5.25 ± 0.37	4.98 ± 0.48
Uropodidae 1	2.78 ± 0.35	2.38 ± 0.31	3.45 ± 0.36	5.13 ± 0.29	2.58 ± 0.38*
Uropodidae 2	2.30 ± 0.40	2.24 ± 0.37	2.96 ± 0.41	6.05 ± 0.33	3.18 ± 0.47*
Uropodidae 3	2.42 ± 0.32	2.11 ± 0.29	2.89 ± 0.39	5.00 ± 0.45	3.65 ± 0.40*
Uropodidae 4	3.91 ± 0.52	2.95 ± 0.40	3.43 ± 0.32	7.55 ± 0.34	3.58 ± 0.35*
Trachyuropodidae	4.27 ± 0.42	3.14 ± 0.37	3.41 ± 0.35	4.85 ± 0.31	3.85 ± 0.39
Polyaspidae	4.02 ± 0.35	3.75 ± 0.30	3.19 ± 0.32	6.05 ± 0.36	3.65 ± 0.42*
Juveniles	3.06 ± 0.45	7.36 ± 0.31	2.84 ±0.27*	4.10 ± 0.43	2.50 ± 0.41*
ACTINEDIDA					
Smarididae	4.19 ± 0.39	2.69 ± 0.30	3.38 ± 0.30	3.34 ± 0.45	2.85 ± 0.43
Bdellidae	3.71 ± 0.44	3.06 ± 0.40	3.62 ± 0.31	2.88 ± 0.35	3.10 ± 0.38
Eupodidae	3.72 ± 0.37	3.91 ± 0.30	3.61 ± 0.35	4.50 ± 0.41	3.83 ± 0.49
Juveniles	1.35 ± 0.34	2.41 ± 0.32	2.08 ± 0.30	3.15 ± 0.46	3.15 ± 0.45
COLLEMBOLA					
Cryptophygus sp.	4.16 ± 0.37	3.86 ± 0.40	3.88 ± 0.39	9.05 ± 0.47	3.58 ± 0.46*
Rhodanella sp.	3.91 ± 0.40	3.65 ± 0.41	4.61 ± 0.36	7.85 ± 0.32	3.68 ± 0.47*
Dicranocentrus spp.	3.97 ± 0.38	3.28 ± 0.40	3.05 ± 0.29	7.88 ± 0.34	2.95 ± 0.41*
Lepidocyrtus spp.	3.27 ± 0.37	4.14 ± 0.32	3.24 ± 0.38	7.95 ± 0.40	3.73 ± 0.51*
Dicyrtoma sp.	4.55 ± 0.36	3.73 ± 0.35	3.35 ± 0.34	7.55 ± 0.32	3.65 ± 0.49*
Paronella spp.	3.88 ± 0.42	4.05 ± 0.37	3.58 ± 0.37	6.95 ± 0.39	3.75 ± 0.44*
Proisotoma sp.	4.77 ± 0.54	4.86 ± 0.44	3.9 ± 0.42	6.13 ± 0.42	3.55 ± 0.41*
Pseudochorutes sp.	3.80 ± 0.35	3.14 ± 0.29	3.05 ± 0.37	5.60 ± 0.39	3.05 ± 0.44*
Ceratrimeria sp.	4.21 ± 0.35	3.89 ± 0.32	4.24 ± 0.36	5.73 ± 0.34	3.58 ± 0.42*
Tullbergia sp.	3.89 ± 0.39	3.59 ± 0.28	4.11 ± 0.37	5.45 ± 0.35	3.98 ± 0.31*
Juveniles	3.79 ± 0.11	5.98 ± 0.40	3.92 ±0.44*	3.78 ± 0.39	3.23 ± 0.41

* Difference significant at 0.05 level of probability.

The mite genera and families as well as springtails whose adult populations increased in response to poultry litter a year after the soil amendment include *Annectacarus*, *Mixacarus*, *Haplozetes*, *Mesoplophora*, *Scheloribates*, *Bicyrthermania*, *Belba*, *Machadobelba*, *Protoribates*, Family Otocepheidae (Oribatida); Families Uropodidae, Trachyuropodidae and Polyaspidae (Uropodina); *Cryptophygus*, *Rhodanella*, *Dicranocentrus*, *Lepidocyrtus*, *Dicyrtoma*, *Paronella*, *Proisotoma*, *Pseudochorutes*, *Ceratrimeria*, *Tullbergia* (Collembola). The increase in their juveniles in response to poultry litter must have resulted in their population increase through maturation of the juveniles and possible multiple recruitment between the treatment (2011) and post-treatment (2012) periods. Badejo and Lasebikan (1988), Badejo (1990) and Badejo and van Straalen (1993) had already reported that oribatid mites and springtails in the same zone undergo multiple recruitment during the annual cycle. It is a well-known fact that during decomposition, succession of living organisms takes place while organic matter gets reduced simultaneously until it becomes completely degraded chemically (Wallwork, 1976). This situation must have occurred in the experimental plots where the densities of all the detritivorous groups were higher in 2012, a year after soil amendment, than in 2010 when poultry litter was yet to be added. Several lines of evidence have revealed that abundance of dead organic matter in the soil influences community structure, species richness and relative abundance of soil-dwelling detritivorous microarthropods through their ability to ameliorate soil microclimatic conditions (Tian *et al*., 1997; Badejo and Tian, 1999). That all springtail species benefitted immensely from the soil amendment is in consonance with the report of Hopkin (1997) that majority of springtails are both detritivorous and mycophagus, feeding on both the decomposing organic matter and the microorganisms on them in the extremely damp and humid environment which the experimental plots provided.

The oribatid mite genera (*Atropacarus*, *Pergalumna*, *Galumnella*, *Teleiolides*, *Oppia*, *Dolichemereus*) whose populations did not increase in response to poultry litter, most probably contain species whose demand on the environment is higher than others either due to their relatively large size or as a result of their obligatory sexual reproduction both of which make their energy demand on the environment more than those of other asexual and facultative sexual species (Balogh and Mahunka, 1983; Norton,1990).

CONCLUSION

The results of this study have shown clearly that the beneficial effect of soil amendment with poultry litter on soil-dwelling mites and springtails may not be noticeable until the year following application. This implies that the consequent release of nutrients from the decomposing litter by bacteria and fungi may take a longer period. The expected increase in soil fertility may, therefore, not occur in the first season of application. Thus, poultry litter application may have to be applied every planting season for many years before its effect on soil fertility is fully realised. This confirms that poultry litter and by extension, all organic manure have the potential of long term increase in soil fertility without any negative consequence to the environment.

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