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Full Length Research Paper

Termite assemblages in the banana agroforestry systems of Kiboga District, Central Uganda

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Agroforestry could be a low cost and environmentally-friendly entry point for addressing declining soil fertility problem in banana cropping systems of Uganda. Trees recycle nutrients from deep soil layers through leaf litter-fall and then, decomposition. Agroforestry systems are known to influence termites, the most important decomposers in tropics. A study was therefore conducted in the banana agroforestry systems of Kiboga district, central Uganda to assess the influence of tree species, seasons, intensity of tree pruning and microhabitat on termite assemblages. Termite assemblage encountered was species-poor, with only 13 species, dominated by genus *Macrotermes* (23%) and sub-family Macrotermitinae (69%). Overall, 359 termites encounters were observed, with *Pseudo canthotermes militaris* being the most abundant species (99 encounters). Only relative abundance of termites varied significantly (p≤0.05) among tree species, seasons, pruning regimes and microhabitats. Highest encounters were observed underneath *Ficus natalensis* canopy (0.4), in part due to its thick canopy that provides cool microenvironment that promotes survival of termites. Additionally, the dry season and pruning increase availability of food resources (litter/woody material) for the Macrotermitinae termites. In conclusion, *F. natalensis* pruned at 50% proved to be the best-bet banana-agroforestry system for conserving and promoting termite assemblages.

Keywords: Abundance, agro-forestry, diversity, richness, termite-assemblages.

INTRODUCTION

The current average farm yields of highland bananas in Uganda of 5-30 Mg $ha^{-1}yr^{-1}$ are still far below the estimated potential yield of over 70 Mg $ha^{-1}yr^{-1}$ (van Asten et al., 2004). One of the major causes of this is declining soil fertility (van Asten et al., 2012; Nyombi, 2013). This problem is more pronounced in the central compared to other major banana growing regions such as southwestern Uganda (Gold et al., 1999; van Asten et al., 2011). The situation is exacerbated by farmers' inability and low use of inorganic fertilizers due to poverty and limited subsidies (Sseguya et al., 1999; van Asten et al., 2004; Muzoora et al., 2011). Most smallholder farmers therefore rely on organic supplements to replenish their soils (van Asten et al., 2004; Mpiira et al.,

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2013).

Nevertheless, research and extension are currently promoting agroforestry as a low-cost and environmentally-friendly approach to replenish soil fertility in order to improve banana production in Uganda (Mpiira et al., 2013) and elsewhere (Pinho et al., 2012). Traditionally, banana agro-forestry systems are common on many smallholder farms in Uganda (Oduol and Aluma, 1990; Oluka-Akileng et al., 2000; Nyombi et al., 2006; Sebukyu and Mosango, 2012; Mpiira et al., 2013) and elsewhere (Akyeampong et al., 1999; Dold et al., 2010). Trees enhance soil fertility by capturing nutrients from deeper soil layers and adding them to the surface soil through leaf fall and incorporation of pruned biomass (Gupta et al., 2010; Berhe and Retta, 2015). They also modify below-canopy air temperature and moisture (Negrete-Yankelevich et al., 2008; von Arx et al., 2012), creating suitable microclimate that promote assemblages of soil biota and hence their ecological activity (Barrios et al., 2012; Berhe and Retta, 2015). Among soil biota, termites are dominant and most important decomposer community in tropics (Collins, 1983; Wardle, 2002). They also play a major role as mediators of nutrient and carbon fluxes (Bignell et al., 1997).

Termite-mediated decomposition processes are governed to a large extent by the functional composition of local assemblages (Davies, 2002; Schuurman, 2006). However, termite assemblages associated with banana agroforestry systems in Uganda are yet to be fully described (Ssebulime, 2017). This information forms the basis for designing and promoting best-bet banana-agroforestry systems for improving banana production, thus, enhancing food security and income of smallholder farmers. Basing on the above backdrop, we therefore determined the influence of tree species, season, tree pruning and microhabitat on the termite assemblages in the banana agro-forestry systems of Kiboga district, central Uganda.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Kisweeka parish, Lwamata sub-county, Kiboga District, central Uganda in 2012. The district lies between 1^o 30‟N and 32^o 14‟E at 1000-1200 m above sea level (a.s.l) (KDLG, 2012). The area has a mean annual temperature of about 25^{o}C and receives a total annual rainfall of 1000-1400 mm that is distributed in a bimodal pattern (Musinguzi et al., 2015). Its soils are classified as Ferralsols (IUSS Working Group, 2006) and characterized by soil fertility limitations such as low pH, phosphorus and cation exchange capacity (Musinguzi et al., 2015). Farming is the main economic activity in the district; with bananas, beans, coffee, cassava, maize and sweet potatoes as the main crops (KDLG, 2011).

Farm selection and tree canopy pruning

Thirty (30) farms were randomly selected in five (5) villages (6 per villages) of Kisweeka parish for the study. The criteria used for selecting the parish, villages and participating farms are described in details in Ssebulime (2017). This study identified four (4) commonest tree species associated with bananas in Kiboga district which were used in the study, namely, *Albizia coriaria*, *Artocarpus heterophyllus*, *Ficus natalensis* and *Mangifera indica*. In each village, one (1) farm with three (3) of each of the above-mentioned tree species was purposively selected. The selected tree species were subjected to one of the canopy pruning treatments: - 0% (unpruned), 25% and 50% of the secondary branches removed (Pinkard and Beadle 1998). The branches were pruned off using three cut procedures to avoid splitting and damage during pruning. The pruning was done using a hand saw and as close to the stem as possible.

Termite sampling

Termites were sampled in the various microhabitats including: - baits, surface leaf litter, woody materials and soil monolith underneath the selected tree species. Sampling was done in both wet and dry seasons. We installed four (4) tissue paper rolls (roll size: 10cm × 12cm × 250cm of 250 sheets, unscented and unbleached tissue; hereafter referred to as baits; Kagezi et al., 2011). The baits were reinforced with masking tape at each end so as to prevent unraveling (LaFage et al., 1973; Kagezi et al., 2011; Olugbemi, 2013). They were then placed surrounding a litter bag that were for a parallel litter decomposition experiment (Fig. 1; Ssebulime, 2017). Before placing the baits, any surface litter was removed to ensure that the baits were in contact with the soil. The baits were then held upright in position by U-shaped steel pins inserted centrally through them and covered with polythene bags to protect them from heavy rains (Kagezi et al., 2011). The baits were inspected regularly at 14, 28, 42 and 56 days intervals after placement. At each sampling, one (1) bait trap was lifted and searched for termites and then discarded (not placed back).

In addition, a 1 m^2 quadrant was demarcated randomly 2 m from the tree trunk and all the surface litter and woody materials present were searched for termites. A standard soil monolith (25x25x30 cm; Swift and Bignell, 2001) was also excavated within the center of the quadrant and searched for termites. The termites encountered were recorded as number of occurrences which is a surrogate for relative abundance (Davies, 2002). A sample of the

Figure 1: Tissue paper roll baits for sampling termites placed around a litterbag

encountered termites was preserved in vials containing 75% alcohol for laboratory analysis. They were identified to family, sub-family, genus and species or morph species levels at the National Agricultural Research Laboratories Institute (NARL), Kawanda.

Data analysis

Before analysis, encounter data were tested for normality and since they were not meeting the statistical assumptions, they were subjected to a double square transformation to remove variance heterogeneity (Clarke and Green, 1988). Analysis of variance (ANOVA) was then performed with general linear model (GLM) procedure. Means were separated by Tukey's test at 5%. Variations in number of encounters across seasons were compared by unequal pairwise t-test with degrees of freedom estimated by Satterthwaite's method. In addition, species richness and diversity across the tree species, seasons, pruning regimes and microhabitats were compared with a Chi square analysis. All analyses were done in SAS v. 9.1 for Windows (SAS, 2008).

RESULTS

Termite assemblages encountered in the banana agro-forestry systems

Table 1 summarizes the termite assemblages and their respective relative abundances encountered underneath the four commonest tree species associated with banana agro-ecologies of Kiboga district, central Uganda. Thirteen (13) termite species belonging to nine (9) genera, four (4) sub-families and two (2) families were observed. Most (69.2%) of termites encountered belonged to sub-family Macrotermitinae, with *Macrotermes* being the most (23.1%) represented genus. On the other hand, termite assemblages comprised of three feeding groups, with group II (wood, litter and grass

Table 1. Termite assemblagesencountered in banana agro-forestry systems of Kiboga district, Uganda.

Family	Sub-family	Termite species	Feeding group	Number of hits
Rhinotermitidae	Rhinotermitinae	*Schedorhinotermesputorius*	I	4
Termitidae	Macrotermitinae	*Bellicostermesspp*	II	6
		Macrotermesbellicosus	II	56
		Macrotermesspp	II	27
		Macrotermessubhyalinus	II	7
		Odontotermesrectanguloides	II	79
		Odontotermestanganicus	II	13
		Pseudocanthotermesmilitaris	II	99
		Pseudocanthotermesspp	II	7
		Sphaerotermesspp	II	6
	Nasutitermitinae	*Eutermesarborum*	IV	41
		Nasutitermesarboreus	IV	5
	Termitinae	*Cubitermesspp*	IV	9
Total number of termite encounters				359
Total number of termite species				13

feeders) dominating (69.2%). Overall, 359 termite encounters were recorded, with *Pseudo canthotermes militaris* and *Odontotermes rectangulo ides* being the most prominent species observed (99 and 79 encounters, respectively).

Effect of tree species, seasons, pruning intensity and microhabitat on species richness, diversity and abundance of termites

Among the four (4) parameters, only the relative abundance of termite varied significantly (p≤0.05) across the tree species (Table 2), seasons (Table 3), pruning intensity (Table 4) and microhabitat (Table 5). Highest termite mean encounters were observed underneath *Ficus natalensis* canopy (0.4), in dry season (0.2), under 50% pruning regime (0.3) and in surface litter (0.3). Further, *Pseudo acanthotermes miltaris* was the most abundant termite species observed underneath *F. natalensis* canopy (42 encounters) whereas *Odontotermes rectangulo ides was* most abundant in the dry season (59 encounters), under 50% pruning regime (43 encounters) and in surface litter (52 encounters).

DISCUSSION

Our results revealed that termite assemblages in the study area were remarkably species poor, with only 13 species were encountered, compared to 25 species observed by Okwakol (2000) in and around Mabira forest, Uganda. However, this finding is in line with observations by Mugerwa et al. (2011a) in the neighboring district of Nakasangola of only 16 termite species. The low number of species encountered in our study could have been in part due to the small size of the sampling unit that calls for a need to increase the sampling effort (Godoy et al., 2012). Majority of the termites encountered belonged to the Macrotermitinae sub-family and genus *Macrotermus*. This corroborates with other studies conducted in Uganda by Sekamatte (2001), Nyeko and Olubayo (2005) and Mugerwa et al. (2011a). These termites are found throughout the savannas and wooded steppes of tropical Africa, below altitudes of 1800-2000 m (Mugerwa et al., 2011a).

In terms of functional composition, most of the termite species recovered belonged to feeding group II (Donovan et al., 2001), agreeing with Mugerwa et al. (2011a). This group contains the fungus-growing termites that feed on wood, litter and grass (Donovan et al., 2001) which are common in farmlands (Togola et al., 2012). Further, the termite assemblage structure was dominated by species from genera *Pseudacanthotermes* and *Odontotermes*. This finding however contradicts Sekamatte (2001) and Mugerwa et al. (2011a) who reported that the dominant species in Nakasongola rangelands belonged to genera *Macrotermes* and *Cubitermes*. This discrepancy could probably in part be due todifferences in food and foraging requirements for the species in question. *Pseudacanthotermes* and *Odontotermes* prefer feeding on dead leaf and wood litter (Davies et al., 1999; Donovan et al., 2001) and these materials are more common in farmlands (Togola et al., 2012). *Macrotermes* species on the other hand, are generalist feeders that can forage on various organic resources such as grass, wood, dung and plant debris (Wood, 1991; Donovan et al., 2001). Also, *Macrotermes* and *Cubitermes* species are associated with low soil moisture content (Attignon et al., 2005; Mathieu et al., 2009), characteristic of Nakasongola rangelands (Mugerwa et al., 2011b).

Results further showed that the relative abundance of termites significantly varied across tree species (Kipkorir, 2015), with the highest encounters being observed underneath *Ficus natalensis* tree canopy. This is in part

Table 2. Species richness, diversity and abundance of termites encountered underneath the canopies of the four (4) commonest tree species in banana agro-forestry systems of Kiboga district, Uganda

Termite species	Tree species				P value
	Albiziacoriaria	*Artocarpusheterophyllus*	*Ficusnatalensis*	*Mangiferaindica*	
*Bellicostermes*spp	0	0	6	0	
*Cubitermes*spp	4	0	4	1	
Eutermesarborum	13	1	21	6	
Macrotermesbellicosus	14	7	27	7	
*Macrotermes*spp	3	5	12	7	
Macrotermessubhyalinus	1	0	6	0	
Nasutitermesarboreus	1	0	4	0	
Odontotermesrectanguloides	22	10	35	11	
Odontotermestanganicus	3	0	7	3	
Pseudocanthotermesmilitaris	29	13	42	15	
*Pseudocanthotermes*spp	3	0	4	0	
Schedorhinotermesputorius	0	0	4	0	
*Sphaerotermes*spp	1	0	5	0	
Total number of species	11	5	13	7	0.2173
Shannon-Weaver index (H')	1.869	1.416	2.185	1.746	0.9826
Mean±SD termite hits	0.2±0.4 (0.2±0.5) b	0.1±0.3 (0.1±0.3) c	0.3±0.5 (0.4±0.6) a	0.1±0.3 (0.1±0.4) c	<.0001

Same letters within a row indicate means (after double square root transformation) are not significantly (*P≤0.05) different across tree species by Tukey's test. Values in parenthesis are the untransformed means.

due to variation in the amount of canopy possessed by the different trees, with higher canopy sheltering a greater number of termites (Lin, 2007; Lott et al., 2009; Boggs and McNulty, 2010). *F. natalensis* generally has a bigger canopy compared to the other tree species (Kagezi et al., 2013) and thus support more termites (Dibog et al., 1999). Termites require cool microclimates to avoid desiccation (Eggleton et al., 1997; Dibog et al., 1999; Eggleton et al., 2002). Also, the cool environment promotes the foraging activities of the termites (Smith and Rust ,1994; Harahap et al., 2005; McManamy et al., 2008; Gautam, 2011). Subterranean termites have been reported not to forage in areas where soil surface temperatures are either too hot or too cold (Haverty et al., 1974; LaFage et al., 1976; Smith and Rust, 1994).

The relative abundance of termites was significantly higher in dry than wet season. This is in line with findings by Basu et al. (1996) and Kemabonta and Balogun (2014). This could in part be due to variation in factors such as habitat preference, food and moisture availability which are known to influence the number of termites (Araújo et al., 2015). Most termites observed in this study belong to the sub-family Macrotermitinae and this sub-family is known

Table 3. Species richness, diversity and abundance of termites encountered in the different seasons in banana agro-forestry systems of Kiboga district, Uganda.

Termite species	Season		P value
	Dry	Wet	
*Bellicostermes*spp	3	3	
*Cubitermes*spp	1	8	
Eutermesarborum	18	23	
Macrotermesbellicosus	52	4	
*Macrotermes*spp	26	1	
Macrotermessubhyalinus	4	3	
Nasutitermesarboreus	1	4	
Odontotermesrectanguloides	59	19	
Odontotermestanganicus	9	4	
Pseudocanthotermesmilitaris	43	56	
*Pseudocanthotermes*spp	4	3	
Schedorhinotermesputorius	2	2	
*Sphaerotermes*spp	3	3	
Number of species	13	13	-
Shannon-Weaver index (H')	1.935	1.873	0.9747
Mean±SD termite encounters	0.2±0.5	0.1±0.4	0.0001

to be favored by drier microclimates (Collins, 1983). Secondly, the dry season increases availability of leaf litter and woody materials (Attignon et al., 2005) which are food and nesting resources for the Macrotermitinae termites (Eggleton et al.,1995; Davies et al., 1999; Korb and Linsenmair, 2001). Further, among the termite species observed in the dry season, *O. rectanguloides* was the most abundant. Our results support observations by Schuurman (2006), Nageswara and Sammaiah (2012) and Kemabonta and Balogun (2014). The high nutrient and energy demands by this species due to late production in the dry season increase its foraging behaviors, thus, numbers encountered (Schuurman, 2006).

Tree pruning promotes canopy openness and this in turn influences species richness, diversity and abundance of insect herbivores (Basset et al., 2001). We observed significant increase in the relative abundance of termites with increasing tree pruning intensity. This finding is in line with Sivapalan et al. (1981) and Luke (2010) and could be due to feeding behavior of termites in question. Most of the termites encountered in this study were litter and wood feeders (Donovan et al., 2001), implying that pruning increases availability of their food resources (Eggleton et al., 1997; Richardson et al., 2010; Keng and Rahman, 2012). Further, *O. rectanguloides* was the most abundant termite species observed under the 50% tree pruning regime, implying that this species was most favored by canopy openness. In fact, genus *Odontotermus* has been reported to be favored by canopy disturbance (Bhavana et al., 2015) due to its ability to endure environmental changes (Jouquet et al., 2004; Keng and Rahman, 2012).

Being colonial insects, termites are not distributed randomly within habitats, they concentrate around colony centers of different sizes which are scattered unevenly across microhabitats (Eggleton and Bignell, 1995). We encountered termites in various microhabitat components, but only their relative abundance significantly varied across the microhabitats. The highest termite abundance was encountered in surface leaf litter and soil monolith, concurring with Bandeira and Vasconcellos (2002), Hemachandra et al. (2009), Vasconcellos (2010), Godoy et al. (2012) and Kemabonta and Balogun (2014). Most of the termites encountered belonged to Macrotermitinae and these termites utilize litter and soil for food and nesting activities (Donovan et al., 2001; Pulleman et al., 2014). Further, *O. rectanguloides* was the most abundant species in surface leaf litter. Although this genus is generally a wood feeder (Donovan et al., 2001), many species of Macrotermitinae will consume litter in certain circumstances (Lepage et al. 1993).

Table 4. Species richness, diversity and abundance of termites encountered under different tree pruning regimes in the banana agro-forestry systems of Kiboga district, Uganda.

Termite species	Pruning regime			P value
	0%	25%	50%	
*Bellicostermes*spp	0	4	2	
*Cubitermes*spp	2	0	7	
Eutermesarborum	8	16	17	
Macrotermesbellicosus	10	19	26	
*Macrotermes*spp	5	12	10	
Macrotermessubhyalinus	0	0	7	
Nasutitermesarboreus	1	0	4	
Odontotermesrectanguloides	7	28	43	
Odontotermestanganicus	2	1	10	
Pseudocanthotermesmilitaris	27	33	39	
*Pseudocanthotermes*spp	0	4	3	
Schedorhinotermesputorius	0	4	0	
*Sphaerotermes*spp	0	0	6	
Number of species	8	9	12	0.6387
Shannon-Weaver index (H')	1.658	1.858	2.103	0.9738
Mean±SD termite hits	0.1±0.3 (0.1±0.3) c	0.2±0.4 (0.2±0.5) b	0.2±0.4 (0.3±0.6) a	<.0001

Same letters within a row indicate means (after double square root transformation) are not significantly (*P≤0.05) different across pruning regimes by Tukey's test. Values in parenthesis are the untransformed means.

On the other hand, *P. militaris* was the most abundant species observed in soil monolith (Pulleman et al., 2014). Species of this genus *Pseudacanthotermes* feed on litter, grass and wood from the soil surface (Donovan et al., 2001; Dibangou et al., 2012; Pulleman et al., 2014).

CONCLUSION

The termite assemblage encountered in the banana agroforestry systems of Kiboga district, central Uganda was species-poor, with only 13 species. Majority of termites encountered belonged to the fungus-growing Macrotermitinae, with *P. militaris* being most abundant species. Tree species, seasons, intensity of tree pruning and microhabitats influenced only the termite relative abundance with the highest values being encountered underneath *F. natalensis* canopy, in dry season, under 50% pruning regime as well as in surface leaf litter and soil monolith. Therefore, *F. natalensis* tree species pruned at 50% could be the best-bet banana-agroforestry system for conserving and promoting termite assemblages.

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Table 5. Species richness, diversity and abundance of termites encountered under the different microhabitats in the banana agro-forestry systems of Kiboga district, Uganda.

Termite species	Microhabitat				P value
	Tissue paper baits	Soil monolith	Surface litter	Woody material	
*Bellicostermes*spp	0	0	4	2	
*Cubitermes*spp	1	7	1	0	
Eutermesarborum	1	13	19	8	
Macrotermesbellicosus	1	15	15	24	
*Macrotermes*spp	0	4	12	11	
Macrotermessubhyalinus	0	2	0	5	
Nasutitermesarboreus	0	5	0	0	
Odontotermesrectanguloides	1	13	52	12	
Odontotermestanganicus	0	0	11	2	
Pseudocanthotermesmilitaris	28	50	14	7	
*Pseudocanthotermes*spp	3	0	4	0	
Schedorhinotermesputorius	0	2	2	0	
*Sphaerotermes*spp	0	2	0	4	
Number of species	6	10	10	9	0.7462
Shannon-Weaver index (H')	0.795	1.769	1.856	1.930	0.9110
Mean±SD termite hits	0.1±0.3 (0.1±0.3) c	0.2±0.4 (0.2±0.5) ab	0.2±0.4 (0.3±0.6) a	0.1±0.4 (0.2±0.4) bc	<.0001

Same letters within a row indicate means (double square root transformation) are not significantly (*P≤0.05) different amongst microhabitats by Tukey's test. Values in parenthesis are the untransformed means.

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