Role of Termites in Nutrient Recycling and Productivity of Beans: A Case Study of Muni Village, Oluko Sub-County, Arua District, Uganda

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This study examined the role of termites in nutrient recycling and productivity of beans in Muni village. Soil pH and nutrients (nitrogen, phosphorous) were established using standard methods. The productivity of beans (plant height, leaf length, leaf width, number of flowers and number of pods) in termite mound and normal soil types were determined. A tape measure was used to determine the height of the plants, length and width of the first leaf on each plant. Macrotermes bellicosus was the only termite species obtained in the studied mounds of Muni village, Oluko Sub County, Arua district. Old termite mound soils had higher amount of nutrients (N, P) and lower soil pH than normal (non-mound) soils. The productivity of beans grown in termite mound soils was higher than that in normal soils hence the termite mound soils which are enriched with phosphorus and nitrogen nutrients can be used to amend nutrient deficient soils for growing of beans and other crops.

Keywords: Beans, Nutrient Recycling, Productivity, Termites

1 Introduction

Agriculture is the backbone of Uganda and is one of the major economic activities carried out in Arua district. The district has a total land area of 4274.13 sq.km of which 87 percent is arable. Over 80% of the households in Arua practice subsistence farming using simple garden tools like hoes, pangas, slashers etc. and they majorly grow cassava, beans, sorghum, millet, simsim, sweet potato, ground nuts and maize among others (Arua district local government, 2012).

The predominant soils in Arua district are ferralitic and sand loams which are fine textured with loose structure, easily erodible, and acidic (Kajubi et al., 2014). They are typically characterized by low nutrient retention capacity, and low available phosphorus (Jianping, 1999; Mattina et al., 2004). Moreover, most plants need well drained, moderately fine to medium textured soils, with optimum physical and chemical properties for growth. Similarly, beans grow in well drained, organic matter rich and fertile soils with soil moisture levels maintained near field capacity to prevent root rot diseases and slow plant growth. Unfortunately, Arua district has a declining rate of soil fertility due to nutrient mining and high population pressure (MFPED, 2010). According to the NEMA (2016), low crop yield due to declining soil fertility is one of the major threats to the Agriculture and crop sector in Uganda including Arua district. The National Environment Management Authority (2006/07) reported decline of soil fertility in Arua district. The soil degradation in Arua district is attributed to poor farming malpractices like bush burning, continuous cultivation, deforestation, poor farming methods, soil erosion among others (NEMA, 2006/07). The low fertility of highly weathered soils has been a major problem for resourceconstrained smallholder farmers who have limited financial resources to purchase commercially available fertilizers (Apori et al., 2020). Nevertheless, the soil conditions can be improved by termite activity and termite mounds are regarded as nutrient hotspots (Ackerman et al., 2007).

However, the role of termites in soil nutrient recycling and productivity of beans in termite mound soils have not been clearly established especially in Muni village, Oluko Sub County, Arua District. Therefore, this study examined the role of termites in nutrient recycling and productivity of beans in Muni village, Oluko Sub-county, Arua District. The specific objectives of this study are to (i) establish the soil pH and nutrients (N,P) in termite mound soils and normal soils in Muni village and (ii) determine the productivity (number of pods, number of flowers, leaf width, leaf length, plant height) of beans grown in termite mound soils and normal soils in Muni village.

2 Materials and Methods

2.1 Geographical Location of the Study Area

The Study was conducted in Muni village, Oluko Sub County, Arua district in northern Uganda (Figure 1). Muni village neighbors Nyio village to the east, Onzivu village (west), Ocholini village (north) and Offudde (south). Arua district is bordered by Yumbe district to the north, Adjumani (northeast), Amuru (east), Nebbi (southeast), Zombo (southwest), Democratic Republic of Congo (west), and Maracha district (northwest). The district headquarters at Arua are located about 520 kilometres, by road, northwest of Kampala, the capital and largest city of Uganda (Arua district local government, 2012).

2.2 Soil Sampling for Nutrient Analysis and Productivity

The study was conducted from March to April 2019. Samples of young and old termite mounds were purposively selected after a survey that was conducted to determine the termite species in the various mounds of Muni village. The collected termite species were put in a Petri dish and compared against the standard termite species check list for proper identification (Wanyonyi et al., 1984).

Four soils samples each were collected from old mound (> 20 years) soils, young mound (< 3 years) soils, mixture of mound and non-mound soils, normal (non-mound) soils to carry out the nutrient analysis and to grow the bean plants. A total of sixteen soil samples were obtained from the various soils under study. Ten bean plants were planted in each of the four different soil categories.

Equal proportions of termite mound soils and normal soils were mixed thoroughly to determine the efficiency of mixing the different soils types on the productivity of beans. Normal soils (non-mound soils) around the sampled termite mounds were also obtained to act as a control experiment in the determination of the productivity of beans.

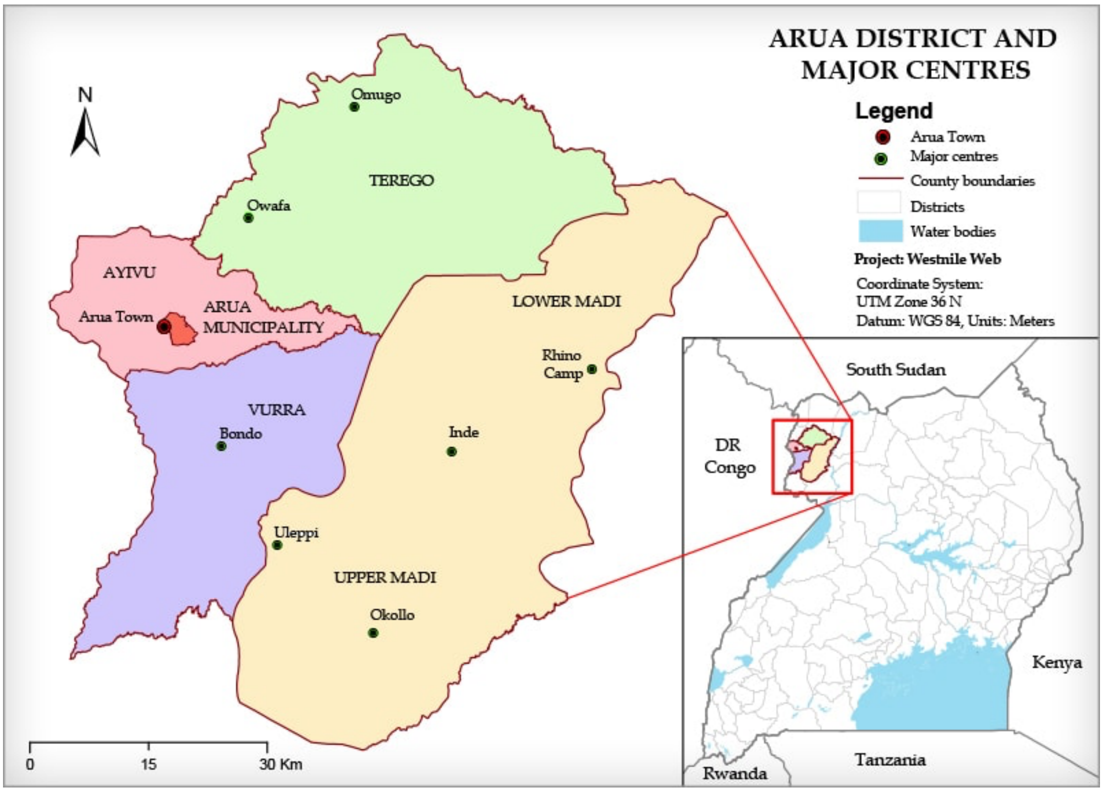

Figure 1: Map showing the location of Arua district and major centers

2.3 Method for pH and Nutrient Analysis

Soil pH tester was used to measure the pH of the different categories of soil obtained from Muni village. LaMotte Soil test kit (modelSTH-4, code 5029) procedures were used to test the amount of nitrogen and phosphorous.

2.4 Determination of Productivity of the Beans

An informal experimental design (i.e., after with control design, Kothari, 2004) was used to determine the influence of termite mound soil on the productivity of beans. The experimentation involved the researcher planting beans in potting bags containing old mound (> 20 years) soils, young mound (< 3 years) soils, mixture of mound and non-mound soils, normal (non-mound) soils. The researcher then compared the productivity of beans grown under the four soil categories. Productivity of beans was measured in terms of height of the plants, length and width of the first leaves on each plant, number of flowers, and number of pods on each bean plant. This was done after every interval of one week.

A tape measure was used to determine the height of the plants and width of the first leaf on each plant grown under soil obtained from the various termite mounds and those from the normal soils (non-mound soils) of Muni village. Number of pods and flowers on each bean plant grown on the various categories of soil was determined by counting the pods and flowers present on each plant.

2.5 Data Analysis

The amount of pH and nutrients (N, P) in the various soils were tabulated while the weekly trend of the mean values of the productivity parameters were presented using line graphs and bar graphs. The descriptive statistics (minimum, maximum, mean ± standard deviation) of the productivity parameters of the beans were tabulated. One Way ANOVA was used to compare the variation of productivity of beans in Muni Village under different soil types. Results were significant at $p \leq 0.05$. Data presentation and analysis were done using SPSS 20 and Microsoft Excel 10 computer packages.

3 Results

3.1 Soil pH and Nutrients in the Soil Categories in Muni village

The termite species identified in the mounds was *Macrotermes bellicosus* with its mound (termitaria) shown in Plate 1 below.

Plate 1: Old termite mound in Muni village from which surface soils were obtained for production of beans.

Generally, termite mound soils had lower pH compared to the non-mound soils of Muni village, Oluko Sub County, Arua district (Table 1).

Table 1: pH values and soil nutrients in the various soil categories

		Soil Nutrients	
Soil type	Soil pH	N	P
Old mound soil> 20years	6.05	moderate	High
Young mound soil< 3 years	4.85	moderate	Moderate
Normal soil (non-mound soil)	6.93	Low	Low
Mixture of mound &normal soil	6.00	moderate	High

Concentrations of nitrogen and phosphorus were generally higher in termite mound soils than normal soils.

3.2 Productivity of Beans grown in the various soil types of Muni village

Mean productivity of beans increased gradually from week 1 to week 3 in all the soil types (Figure 2). From week 1 to week 2, the leaf length and width increased gradually. From week 2 to week 3, leaf length and width was almost constant in all the different soil types. Plant height in the different soil types constantly increased from week1 to week 3.

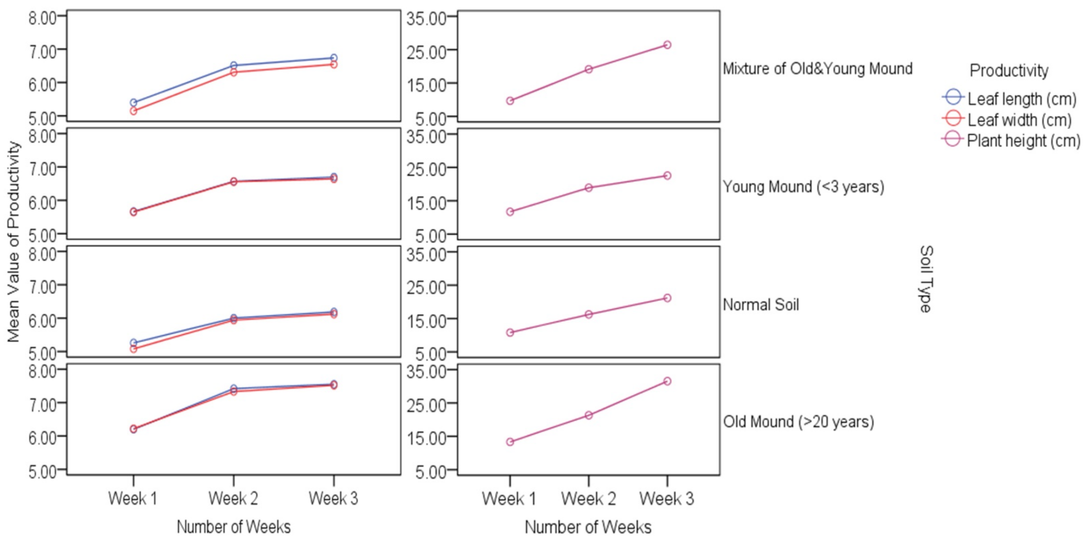

Figure 2: Weekly trend of productivity of beans grown in the different soil types after germination

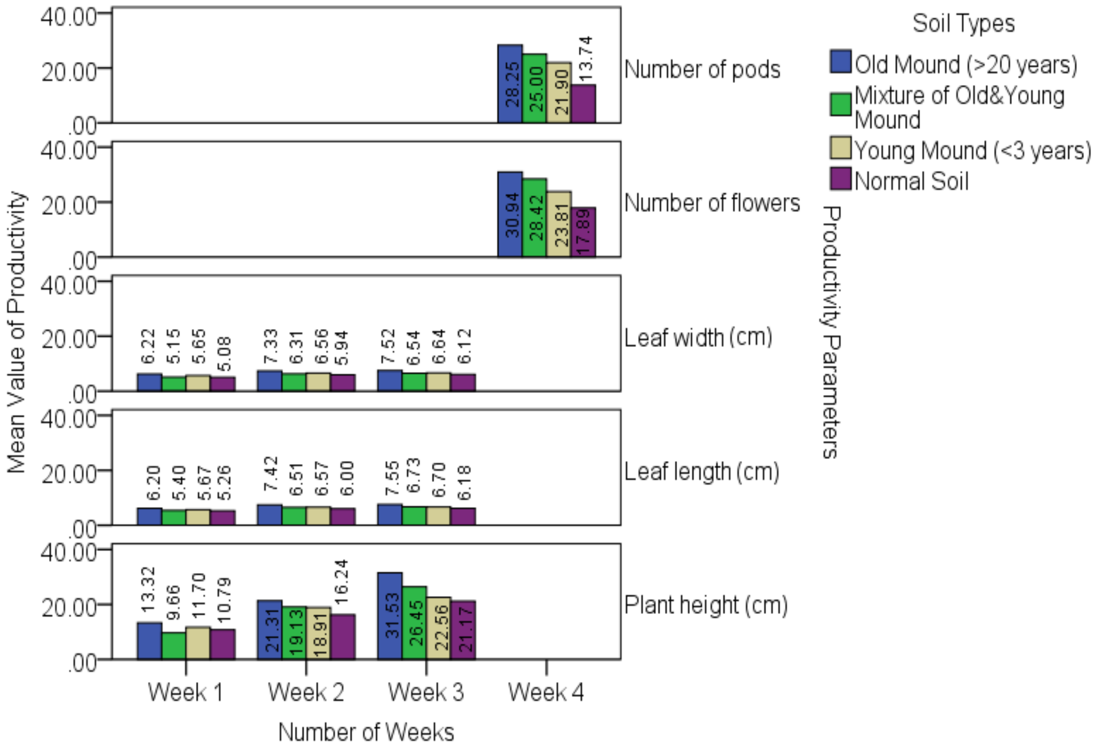

Figure 3: Weekly mean values of productivity of beans grown in different soil types after germination

Table 2: Descriptive statistics and comparison of productivity of beans in Muni village using ANOVA

Productivity Parameter	Soil Type	N	Descriptive statistics Min.	Max.	Mean±SD	ANOVA F	p
Plant height (cm)	Old Mound (>20 years)	48	8.20	42.30	22.05±8.80	6.82	1.96E-04
	Mixture of Old&Young Mound	82	6.50	38.80	18.30±7.70		
	Young Mound (<3 years)	65	8.90	31.10	17.54±5.64		
	Normal (Non-mound) Soil	57	6.50	28.40	16.07±5.37		
Leaf length (cm)	Old Mound (>20 years)	48	3.20	9.20	7.06±1.34	10.77	1.13E-06
	Mixture of Old&Young Mound	81	4.00	8.80	6.20±1.14		
	Young Mound (<3 years)	65	2.80	8.10	6.29±1.11		
	Normal (Non-mound) Soil	57	4.00	7.90	5.81±0.98		
Leaf width (cm)	Old Mound (>20 years)	48	3.00	9.60	7.02±1.63	10.71	1.23E-06
	Mixture of Old&Young Mound	80	3.50	8.20	5.99±1.14		

	Young Mound (<3 years)	65	4.20	8.20	6.26±1.09		
	Normal (Non-mound) Soil	57	3.80	7.80	5.71±1.17		
Number of flowers	Old Mound (>20 years)	16	23.00	43.00	30.94±5.86	21.93	2.14E-10
	Mixture of Old&Young Mound	26	19.00	39.00	28.42±5.47		
	Young Mound (<3 years)	21	14.00	36.00	23.81±5.64		
	Normal (Non-mound) Soil	19	11.00	24.00	17.89±4.05		
Number of pods	Old Mound (>20 years)	16	20.00	39.00	28.25±5.63	27.45	3.21E-12
	Mixture of Old&Young Mound	26	15.00	35.00	25.00±5.39		
	Young Mound (<3 years)	21	12.00	33.00	21.90±5.37		
	Normal (Non-mound) Soil	19	7.00	20.00	13.74±3.80		

N=Number of measurements; Min.-Minimum; Max.-Maximum; SD-Standard Deviation

Old termite mound soil > 20years in Muni village, Oluko Sub County, Arua district had significantly ($p<0.05$) the highest productivity of beans (Plant height, Leaf length, Leaf width, Number of flowers and Number of pods) followed by the mixture of mound and non-mound soil and lastly the non-mound (normal) soil (Figure 3; Table 2).

4 Discussion

4.1 Soil pH and Nutrients in the Soil Categories in Muni village

The termite species found in the termite mound in this study (*Macrotermes bellicosus*) is one of the termite species of Northern Uganda reported by Pomeroy (1977) with the structure of the termite mound similar to that of Mali et al. (2018). This termite species establishes their mounds in the lowlands within crop gardens.

Termite mound soils had slightly lower pH than non-mound soils though they were all acidic. Relatively similar pH values were obtained by Abe et al. (2011) in mounds of *Macrotermes bellicosus* in the southern Guinea savanna zone of Nigeria. The acidic nature of the mound soils can be attributed to the decomposition of plant matter by termite activity. Previous studies show that decomposition of organic matter produces humic acids which on hydrolysis cause a decrease in pH (Juma, 1998; Bot & Benites, 2005). However, the acidic soils of the study area concur with the generally acidic nature of soils of Arua district (Kajubi et al., 2014).

The higher concentrations of nitrogen and phosphorus in old termite mound soils than normal soils in Muni village concurs with previous studies which found out that long-lasting termite mounds had higher N, P, and organic matter content than surrounding non mound soils (Wagner, 1997; Whitford, 2002; Belnap, 2011). Termite species of Macrotermes have been reported to concentrate nutrients in the termite mound soil than the adjacent soils (Pomeroy, 1983; Okwakol & Sekamatte, 2007). The mounds of *Macrotermes bellicosus,* are enriched with some nutrients to create hot spots of soil nutrients in the vicinity of the mounds (Abe et al., 2011). The higher amount of N and P in termite mound compared to surrounding soils is attributed to the cumulative effect of organic matter by the termites in their mound (Apori et al., 2020). Termite activity results in decomposition of organic plant matter into component nutrients leading to increased soil fertility since termites are ecosystem engineers (Pardeshi & Prusty, 2010). According to Lavelle and Spain (2001), organic matter decomposition is the source of most of the nitrogen and phosphorus in unfertilised soils. The rate of litter decomposition is higher in *Macrotermes bellicosus* mounds (Pomeroy, 1978).

4.2 Productivity of Beans grown in the various soil types of Muni village

Old termite mound soil > 20years recorded the highest productivity of beans (Plant height, Leaf length, Leaf width, Number of flowers and Number of pods) due to high accumulation of nutrients over time needed for plant growth as a result of increased termite activity. Mean productivity of beans in the mixture of mound and non-mound soil was also high due to the mixture of the different soil components. Non-mound (normal) soil had the least mean productivity of beans due to the low nutrient content needed for plant growth in the soil.

The high productivity of beans in termite mound soils can be attributed to termite activity with the major species of termites inhabiting the mounds of Muni village being *Macrotermes bellicosus* (sub-family, Macrotermitinae) which were responsible for the release of the mineral nutrients for bean plants. According to Pomeroy (1977), *Macrotermes bellicosus* mounds are dominant in areas with the mean maximum temperatures of 28^{o}C. Since Arua district is a semi-arid area with high temperatures, this provides favourable environment for *Macrotermes bellicosus* termite species. *Macrotermes bellicosus* termite species release the mineral nutrients for plant growth at a faster rate (Pomeroy, 1978) hence increasing plant productivity. Therefore, the farmers in Muni village should use the termite mounds to cultivate their beans and other crops around the mounds rather than destroying the mound by physical removal of the mother termite (queen) through excavation which is a common practice in the area due to the destructive nature of some termites. Though the area coverage of termite mounds is not known in Muni village, most farmlands in the village have termite mounds and the soils are generally dominated by termites.

Farmers have been seen to conserve the mounds and plant crops around them or spread termite-modified soils on their fields in some parts of sub-Saharan Africa (Sileshi et al., 2009; Ayuke, 2010; Akutse et al., 2012). Farmers attest that the old mounds of termites are source of nutrients for crops (Akutse et al., 2012; Stoops & Schaefer, 2010; Stoops, 1964). According to them, plants which are grown around these mounds do better because the soils around the mounds are found to be more fertile. In some situations, farmers break the mounds and scatter it to cover more surfaces before the planting or sowing time. The use of termite mound soils as fertilizer has been practiced by some farmers in Uganda (Okwakol & Sekamatte, 2007), Ethiopia (Debelo & Degaga, 2015), Laos (Miyagawa et al., 2011; Shuichi et al., 2011), Zambia, Zimbabwe, Tanzania, Niger, and Sierra Leone (Sileshi et al., 2009). In central Uganda, smallholder farmers have been collecting termite mound soils anywhere around the termite mound to improve their soil fertility (Apori et al., 2020). The farmers amend their poor soils using termite mound soils either solely or in combination with organic resources and fertilizers (Chisanga et al., 2020).

5 Conclusions

Termite mound soils are more enriched with essential nutrients (Nitrogen, Phosphorus) as a result of increased termite activity and are more acidic compared to the normal soils. The productivity of beans grown in termite mound soils of Muni village, Oluko Sub County, Arua district is higher than that in normal soils. Therefore, this study suggests that termite mound soils which are enriched with phosphorus and nitrogen nutrients can be used to amend nutrient deficient soils for growing of beans and other crops. However, further research work on large scale using non-leguminous crops (e.g., cassava, sorghum, millet, sweet potato, maize etc) with several replications, varied soil and environmental conditions and use of quantitative techniques for nutrient analysis is required. The authors further suggest studies on the nutritional value of mound beans versus non-mound beans.

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