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Effect of Termite Mound Soil on Growth and Yield of Sweet Potato *(Ipomoea batatas)* in Western Ethiopia

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Abstract

Termite mound soils (TMS) are utilized as degraded top soil amendment and an alternative to chemical fertilizer for growing crops in some small holder farmers in Africa. However empirical studies on the use of mound soil for production of crops are scanty in African countries including Ethiopia. The present study was undertaken to evaluate the effect of TMS on growth and total root yield of Sweet potato *(Ipomoea batatas (L) Lam)* as compared to adjacent soil with and without application of inorganic fertilizer (NPK) in Gudeya Bila district, Western Ethiopia. A field experiment was carried out during main cropping season in 2019 at three farmers' fields. The treatment combinations were arranged in a complete randomized block design (CRBD) with three replications with sweet potato as testing root crop. Data were analyzed using descriptive statistics and analysis of variance (ANOVA) which was done by using Genstat software 18th Edition. Results showed that on average, significantly higher dry biomass weight (1750±76.4gm/plot) and total root yield (4066.7±23.3gm/plot) of the sweet potato grown in TMS were observed than in adjacent soil with NPK in which dry biomass weight (1533.3±88.2 gm/plot) and root yields (3043.3±26.1 gm/plot) were recorded. But in the control soil, dry biomass (1360±23.1gm/plot) and total root yield (2873.3±16.6 gm/plot) of the plant were recorded. In conclusion, TMS is a promising potential alternative fertilizer for growing root crops such as Sweet potato (*Ipomoea batatas*) and Anchote (*Coccinia abyssinica*) which are favorite cultural crops in the study setting.

Keywords

Adjacent Soil, Gudeya Billa, Sweet Potato, Termite Mound Soil

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1. Introduction

From the economic and agricultural point of view, the activities of termites can have detrimental or beneficial effects. Pestiferous termites damage and destroy agricultural crops, buildings and land escapes which may account to high economic loss in the world [1]. In East Africa, termites pose a major threat to agricultural crops, forestry seedlings, rangelands and wooden structures. In Ethiopia, the problem is most severe in the western parts of the country including Wollega area [2]. High termite infestations are symptoms of land degradation and poor soil fertility, which is caused by overgrazing, deforestation, soil erosion and other factors in the country [3].

On the other hand, termite activities contribute to soil fertility and thus enhance agricultural productivity. Soil-dwelling termites build mounds that have significant impact on the soil environment that result in accumulation of organic matter

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and enrichment of nutrients and minerals in the soil [4]. Studies show that termite mounds contain significantly higher concentration of total nitrogen, calcium, phosphorus, potassium, nutrients and organic matter than adjacent soils and are important for crop production [4-6].

Furthermore the most recent study in Southern Zambia, demonstrated that soil from the top and base sections of the termite mound structures contain potential macro and micro nutrients (P, K, Ca, Mg, Cu, Fe and Zn) which can substantially support crop growth [7]. The same authors suggest that this can play a key role in integrated soil fertility management systems, where manure, crop rotation, intercropping or application of commercially available fertilizer may be used to boost N and P levels in soils lacking these nutrients.

Soil fertility management practices are a major barrier to agricultural production in developing countries including Ethiopia [8]. Declining soil fertility in sub-Saharan Africa (SSA) continues to reduce soil productivity and is a major obstacle to addressing problems of food security [9]. Mineral fertilizers play important role in enhancing soil fertility status and subsequently increases crop yields if judiciously utilized. However, farming with such innovation has not been sustainable because of many limitations among which are high cost, poor distribution network, scarcity, possible soil acidification, especially with acid forming ones, and ground water pollution [6, 9, 10]. The environmental deteriorating effects arising from the misuse of pesticides and chemical fertilizers in agriculture has resulted in the pursuit of eco-friendly means of producing agricultural produce without compromising the safety of the environment [11].

Attention therefore, has shifted to research on organic sources of plant nutrients. Several works have been done on animal manures, crop residues, industrial wastes and bio-fertilizers leaving out termite mound which has potential for improving crop yield where they abound [12, 13].

Termite mound soils are reportedly utilized as an alternative to NPK fertilizers by cash constrained smallholder farmers in some parts of Africa. In Zambia, for instance, cash strapped smallholder farmers have often used termite mound soil to fertilize their crops to cushion against the inorganic fertilizer costs [13-15]. In Ethiopia, farmers have not practiced and used termite mound soils for crop growth, amendment of degraded top soil and as alternative to chemical fertilizer for crop production though termite mounds are rampant across the country particularly in central and southern Ethiopian Rift Valley and western parts of the country [2, 14-15].

Therefore, the overall aim of this study was to assess the impact of termite mound soil on Sweet potato *(Ipomoea batatas)* one of the dominant vegetable root crop in the upper Gibe valley, Western Ethiopia. Sweet potato ranks third after Enset (*Ensete ventricosum)* and Potato (*Solanum tuberosum L.*) as the most important root crops produced for human consumption in the country. In addition to being drought tolerant and having a wide ecological adaptation, it has a short maturity period of three to five months for maintaining household food security.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted in Gudeya Bila district (GBD) in the upper Gibe valley, Western Ethiopia. Geographically GBD lies between the latitude of 37°01′28″N and longitude of 9°17′23″E. The altitude of the district ranges from 500 to 3500 m.a.s.l. It is located 105km from Nekemte, the capital of East Wollega zone and 276km from Addis Ababa the Ethiopia capital (Figure 1). The climate of the study area is categorized under tropical and sub-tropical regions, with an average annual precipitation of 1600mm to 2000 mm and average annual evaporation ranging from 3200mm to 4400 mm. The mean annual temperature of the study area varies between 11.3°C to 23.36°C. The annual average rain fall of the district varies between 1400 to 2000mm (Gudeya Bila Administration Office, 2011).

The total population of the district were 72, 624 of whom 35,945 were men population, and 36,679 were women population), Out of these, 63,967 (88.08%) were the rural population while 8,657 (11.92%) were urban dwellers during the study time. It had a total area of land 842.75 km^2 (84,275) hectares. The economic activities of the local community of the study area are primarily mixed farming system that involves both crop production and animal husbandry. The livelihood of the district is best known for production of major crops such as teff, maize, wheat, barley, coffee, sorghum, bean, pea and Niger seed (Nug). Households grow teff, maize, sorghum, barley and wheat for consumption and sale, while Nug is grown as a cash crop. Bollworm, termites and stalk borer are known pests in the district (Gudeya Bila Administration Office, 2011).

2.2. Experimental Design, Treatments and Applications

To evaluate the effect of termite mound soil on the growth and root yield of sweet potato as compared to adjacent soil with and without application of inorganic fertilizer (NPK), three termite mounds were randomly selected as treatments from long year cultivated land use and the sweet potato was grown insitu on the farmers' field. The field experiment was conducted during main cropping season in 2019 under rain fed condition on three purposively selected farmer fields in Hagalo Gidami kebele in Gudeya Bila district. The study sites were purposively selected because of high impact of termite activity and widespread termite mounds and accessibility of the area.

The study was carried out in three replicates on an area of 2m x 2m ($4m^2$) plots of farm land. The treatments include: termite mound soils, adjacent surface soil with application of inorganic fertilizer and adjacent soil without inorganic fertilizer. The adjacent surface soil without fertilizer was used as control for the study. The treatment combinations were arranged in randomized complete block design (RCBD) with three replications. Sweet potato was used as a testing root crop for the treatment. Blocks and plots were prepared at the beginning of May, 2019 by using labor input with axes according to the design. Planting was done at the end of June, 2019. The radius of each plot was 1m to avoid the influence of erosion and other confounding factors. In each block, equal number and the same variety of sweet potatoes were planted on rows per the plot. The NPK fertilizer was applied in to the treatment plots as recommended for root crops production at a ratio of 100kg/ha (NPK), that was 40gm/plot. In each plot, the plant spacing and row spacing were done by 60cmx60cm with 81 total plant densities in all plots in three treatments with three replications in which 9 plants were planted per plot. After planting, manual weed control and all recommended agronomic practices for the crop were performed during the cropping season, and no chemicals were applied to control pests. Weeding was done by using hand picking.

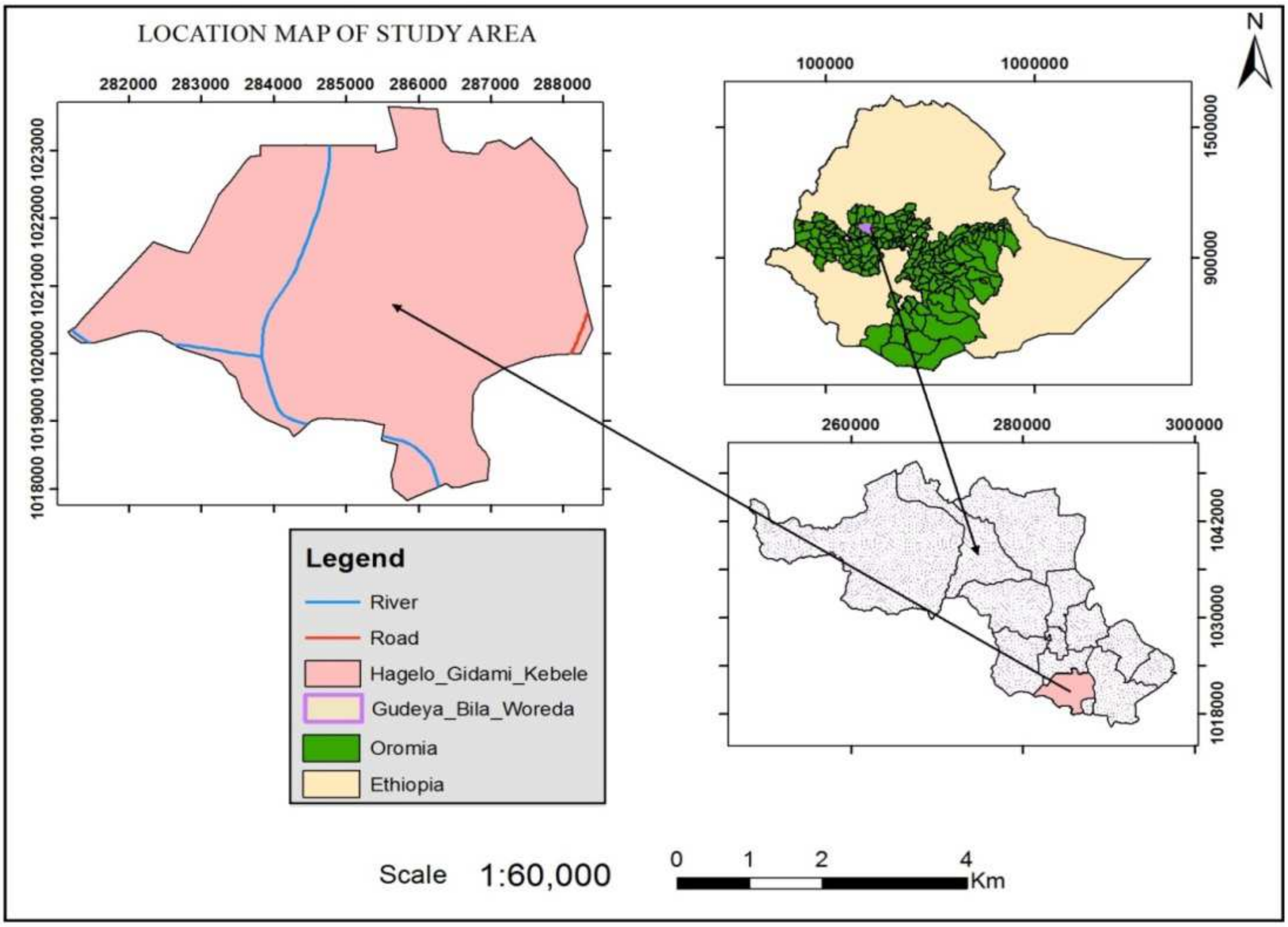

Figure 1. Map of the study site in Gudeya Billa district in Oromia Regional State, western Ethiopia

2.3. Measuring Growth Parameters

The growth parameters such as plant height, number of leaf, number of branch, and leaf area of sweet potato were measured every two weeks after planting, while number of roots, dry biomass weight and total root yield were recorded at the maturity period of sweet potato. Plant height (cm) was recorded for five randomly selected plants from harvestable rows in each plot within consecutive two weeks after planting and it was measured from the base (ground surface) to the tip of main stem of the plant. Number of branches per plant was determined by counting the number of primary branches on the main stem of five randomly selected plants in each plot at physiological maturity. Leaf area was calculated according to Owudike [16] measuring height and diameter of the leaf and then calculating it by using the formula, LA= HXPX0.56 x 6.20 were 'H' is height of the leaf, 'P' is diameter of the leaf and 0.56 and 6.20 are constants which account for the irregularity of sweet potato leafs [16].

2.4. Measuring Root Yield

Total root yield per plot was measured at the end of six months (180 days), at maturity period of sweet potato with in 1m x 1m area of each plot according to Tenaw [17] and Teshome [18]. To determine the average number of roots per plot, five plants were randomly selected from harvestable plots, and the total numbers of roots were counted. Root yield (gm/plot) was measured from each plot at the maturity period of sweet potato. Finally the yield from net plot area of each treatment was was expressed in gram per plot.

2.5. Data Analysis

The effect of termite mound soils on sweet potato production were subjected to analysis of variance (ANOVA) using Genstat software, 18th edition. To compare the significance means variation among the parameters, the Least Significant Difference (LSD) test was employed at ($p<0.05$) level of significance. Finally, the results were presented by using tables and plates.

3. Results

3.1. Effect of Termite Mound Soil on the Growth of Sweet Potato

Sweet potato grown in termite mound soils showed significantly higher ($p=0.001$) plant height, number of branch, number of leaf and leaf area within 2, 4, 6 and 8 weeks after planting as compared to those grown in adjacent soil with NPK and without NPK fertilizer (Table 1 and Figure 2). As it can be seen from the table significantly higher mean value of plant height (165.8cm) was recorded at termite mound soil as compared to the adjacent soil with NPK fertilizer (144cm) and without the fertilizer (134.2cm). Similarly significantly higher mean \values of number of branches, number of leaf and leaf area were recorded for the potato plants grown in termite mound soil as compared to those grown in the adjacent soil with and without the fertilizers.

Table 1. Effect of termite mound soil on the vegetative growth of sweet potato as compared to adjacent soil with and without NPK (Mean ±SE) in the Gudeya Bila district, Ethiopia. a) TMS is termite mound soil, b) ASWF is adjacent soil with fertilizer, c) ASWOF is adjacent soil without fertilizer and d) LSD is the least significant difference test.

Treatment	Plant height (cm)	Number of branch/Plot	Number of leaf/Plot	Leaf area (cm^2)
TMS	165.8±6.4a	47±3.2a	117.6±5.2a	359.35±46.8a
ASWF	144±5.5b	39±2.7b	107.8±5.5b	286.63±63.3a
ASWOF	134.2±5.9c	37.6±2.6b	92.4±5.4c	266.85±58.2b
LSD5%	5.4	2.6	4.8	56.8
Status	**	**	**	**

*Means followed by the same lower case letter with in column do not differ significantly by LSD at 5% of probability ($p<0.05$). **: highly significant at ($p=0.001$) level of significance.

Figure 2. Vegetative growth stage of sweet potato in termite mound soil (left), in adjacent soil with NPK fertilizer (middle) and in adjacent soil without termite soil and NPK fertilizer (right).

3.2. Effect of Termite Mound Soil on Root Yield

Number of roots per plot: The number of roots per plant was significantly varied ($p=0.001$) among the study groups (Table 2 and Figure 3). The higher number of roots per plot (144 root/plot) was obtained from termite mound soil as compared to its adjacent soil with NPK fertilizer (106.67 root/plot) and the adjacent control treatment (88 root/plot).

Root dry biomass (gm/plot): As shown in Table 2, sweet potato dry biomass weight per plot significantly varied among the treatment and control groups. The highest mean dry biomass weight (1,750 gm/plot) was recorded from plants grown in termite mound soil while the lowest mean dry biomass of the plant was recorded from those grown in adjacent control treatment without NPK fertilizer.

Total root yield (gm/plot): The average total root yield (4066.7 gm/plot) of sweet potato grown in termite mound soil was significantly out yielded ($p=0.001$) as compared to those grown in adjacent soil with NPK fertilizer (3043.3 gm/plot) and the control soil treatment without NPK (184.8 gm/plot) as well (Table 2 and Figure 3).

Table 2. Effect of termite mound soil on the root yield of sweet potato as compared to adjacent soil with and without NPK (Mean ±SE) in the Gudeya Bila district, Ethiopia. a) TMS is termite mound soil, b) ASWF is adjacent soil with fertilizer, c) ASWOF is adjacent soil without fertilizer and d) LSD is least significant difference test.

Treatment	Number of root/Plot	Dry biomass (gm/Plot)	Total root yield (gm/Plot)
TMS	144 ±9.2a	1750±76. 4a	4066.7±23.3a
ASWF	106.67±14.1b	1533.3±88.2b	3043.3±26.1b
ASWOF	88±4.6c	1360±23.1c	2873.3±16.6c
LSD 5%	13.7	93.3	184.8
Status	**	**	**

*Means followed by the same lower case letter with in column do not differ significantly by LSD at 5% of probability ($p<0.05$). **: highly significant at ($p=0.001$) level of significance

Figure 3. Root yield of sweet potato obtained from termite mound soil (left), adjacent soil with NPK fertilizer (middle) and adjacent soil without termite soil and NPK fertilizer (right).

4. Discussions

The ultimate purpose of the study was to evaluate the effect of termite mound soil on the growth and yield of sweet potato as compared to adjacent soil with NPK fertilizer and without the fertilizer. Results showed that significantly higher mean plant height, number of branch, number of leaf and leaf area of sweet potato were recorded in termite mound soil within 2, 4, 6 and 8 weeks after planting as compared to those grown in adjacent soil with NPK and without NPK fertilizer. The significantly higher plant height, number of branch, number of leaf and leaf area of sweet potato grown in termite mound soil could be an indication of higher nutrient content in this termite modified soil. In line with this result studies indicate that termite mounds contain significantly higher concentration of total nitrogen, calcium, phosphorus, potassium, nutrients and organic matter than adjacent soils which can substantially support crop growth [5, 14, 19]. This is in agreement with Sileshi et al. [14] who observed significantly higher plant biomass and grass growth around mound soil compared with the ones grown far away from mounds. Most importantly, the results are in agreement with Debelo and Degaga [6]; who observed significantly higher stem length, grain yield and dry plant biomass of teff (*Eragrostis teff* L.) grown in the mound perimeter than adjacent soil in the Great Rift Valley of Ethiopia.

Results also show that significantly higher number of roots, dry biomass and total root yield of sweet potato were obtained from the plant grown in termite mound soil than its adjacent soil with and without NPK fertilizer. This would be expected because the higher accumulation of plant nutrients in mound soils have contributed to significantly higher differences in number of roots, dry biomass and total root yield of sweet potato grown in the mound soil than in the adjacent soil treatments. Similarly teff grown in termite modified soil with no application of fertilizer showed significantly higher dry biomass, and grain yield than adjacent soil to which fertilizer was applied and to which no fertilizer was added in central Ethiopia [6]. The same authors reported that maize grown on mound perimeter produces larger cob and thus gives higher yield than the one grown far from mound. From their field observations, they also noted that crops grown on soils in mound perimeter were dark green while the ones grown on adjacent soil were yellowish in color.

At the end, this study was not without limitations, the study was carried out on the effect of termite modified soil on local variety of sweet potato. The effect of the soil on the growth and marketable yields of different sweet potato varieties such as Kabode, Kulfo and Tulla warrant further study.

5. Conclusions

Termite mound soil enhances vegetative growth of sweet potato and root yields as compared to adjacent soil with and without inorganic fertilizer in Gudeya Billa district. This indicates that termite mound soils could be used as an alternative to NPK fertilizer for soil fertility management particularly for amending degraded top soil to improve yields of root crops in the study setting and elsewhere in Ethiopia. Furthermore resource poor farmers who cannot afford to buy chemical fertilizers can use termite mound soil as an alternative for their soil fertility management for the production of root and tuber crops in the country and elsewhere. This finding has contextual local relevance because it can be used for immediate consumption by farmers in Wollega and other western rural communities where the most favorite food is root and tuber crops such as Anchote (*Coccinia abyssinica*) and termite infestations and their mound soils are rampant across this part of the country. It is also ecofriendly soil fertility management for human and environmental safety as compared to chemical fertilizers.

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