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Growth and Yield of Maize (*Zea mays* L.) under Guinea Grass (*Panicum* maximum) Green Manure Fertilization

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Abstract

Growth and yield of maize (*Zea* mays L.) under guinea grass (*panicum* maximum) green manure fertilization was studied in a loamy sand upland soil at the Ernest Bai Koroma University of Science Technology Makeni University College Campus Farm using the variety (*Zea* mays L. cv: DMR-ESR-Yellow). Six treatments (No fertilizer, 200 kg ha^{-1} NPK 15:15:15, 5 t ha^{-1} Guinea grass green manure, 10 t ha^{-1} Guinea grass green manure, 15 t ha^{-1} Guinea grass green manure, and 20 t ha^{-1} Guinea grass green manure) were experimented using a randomized complete block design with each treatment replicated four times, giving a total of twenty-four plots. There were significant differences between treatments for plant height, stem girth, number of leaves, leaf area, dry root weight and grain yield. There was no significant difference between the 200 kg ha^{-1} NPK 15:15:15 and No fertilizer treatments. The 200 kg ha^{-1} NPK 15:15:15 treatment gave the lowest increase in grain yield compared with the green manure treatments. Maize grain yield progressively increased from the 5 t ha^{-1} to the 15 t ha^{-1} Guinea grass green manure rate, but declined at 20 t ha^{-1} manure rate. The 15 t ha^{-1} manure application gave the highest grain yield, leaf area, stem-diameter, and plant height, and was recommended best suited for use for economic and environmental considerations.

Keywords: Guinea grass; Green manure; Growth; Yield; Maize

Introduction

Maize (*Z. mays* L.) belongs to the grass family and originated from Central America [1]. It is believed that the Portuguese introduced it into Africa and West Africa at the beginning of the 16th century [2]. According to Sridhar and Adeoye, maize has a fibrous root system which spreads in the soil [3]. As an annual crop, it has a solid un-branched stem. The plant is characterized by having long narrow leaves and a cob producing numerous grains with high starch content. The mature plant bears a tassel at its tip.

Maize (*Z. mays* L.) is an important cereal due to its high yield, ease of processing, ready digestibility and lower cost than other cereals [4]. It is a carbohydrate used as food, in livestock feed, in the textile and pharmaceutical industries.

Maize has great potentials in the tropics and yields of up to 8 t ha^{-1} can be achieved if the crop is well managed. Unfortunately, global average yields of traditional varieties of maize grown by small-scale farmers are currently below 1 t ha^{-1} [5]. This has caused its shortage for its many uses. Factfish (www.factfish.com) observed that the total maize produced in Sierra Leone from farmers' fields in 2006 was 48,813 tons but decreased to 12,554 tons in 2016. This could be due to the degrading nature of soils, poor fertility management and low imported technology to improve soil fertility. The use of organic manure could be adopted [6]. Following population increases, especially in Sierra Leone (2016 Sierra Leone Population and Housing Census), adequate attention should be directed towards massive and cheapest ways of food production. In order to achieve this, emphasis should be laid on the easiest and cheapest means of enriching our soils and analyzing the key problems which limit production and expansion of crops such as maize. Meanwhile, attempts to use inorganic fertilizers to replenish the soil nutrients have not been successful because of high cost, sometimes, the adulterated nature of the product has adverse effects on the soil, water and plants, hence, there is need to look for other source(s) of maintaining the soil fertility in order to enhance optimum yield of maize.

The application of NPK fertilizers to the soil actually boosts the performance of maize. However, they are easily leached and eroded in the tropics due to high rainfall, reducing the expected yield increase on their application. Their persistent use destroys soil reactions and impedes the activities of soil microorganisms thereby making the soil acidic and toxic to maize [7]. Most importantly, chemical fertilizers are not affordable to resources-poor farmers and so the use of organic manure is of great advantage, because it is cheap and contains many nutrients needed by plants for optimal performance and improves soil texture and structure and increases soil pH. Manures play a great role in sustaining soil fertility as they improve soil water-retention and contribute N, P, K, Ca and other nutrients to it than chemical fertilizers [8]. They are essential constituents of soil and are present in a variety of forms, such as green manure, farmyard manure and compost. Organic manure, when properly applied, benefits fruiting in plants like maize and increases stem size, plant height and number of leaves [9]. Maize tolerates sandy soil, if well supplied with organic materials. On the heavier soils, the yields are usually large and bearing period longer than the lighter soils. The objective of this study was to determine the response of maize to different rates of Guinea grass green manure in comparison to the recommended 200 kg ha^{-1} NPK 15:15:15 treatment on a loamy sand upland soil in Sierra Leone.

Materials and Methods

Experimental site description

A field experiment was conducted at the Ernest Bai Koroma University of Science and Technology Makeni University College Campus, (Latitude 8.53 N, Longitude 12.02 W and 89 m above sea level), Northern Province of Sierra Leone in the rainy season of 2018. The climate is tropical with distinct dry and rainy seasons with mean annual temperature of 30°C. Annual rainfall ranges from 2500 mm-3000 mm [10]. The rainy season usually lasts from May to November and the dry season, December to April.

The site was previously cropped with sweet potato followed by maize and fallowed for a year before the start of this trial. The dominant vegetation was Guinea grass (*M. panicum*). Guinea grass, like elephant grass (*Pennisetum purpureum*) and spear grass (*Imperata cylinderica*) is one of the dominant grasses which farmers incorporate into soils in crop production. The experimental site was cleared of vegetation and plowed.

Experimental design, plot, manure and fertilizer rates

A randomized complete block design was used with four replications and six treatments: No fertilizer, 200 kg ha^{-1} NPK 15:15:15, 5 t ha^{-1} Guinea grass green manure, 10 t ha^{-1} Guinea grass green manure, 15 t ha^{-1} Guinea grass green manure, and 20 t ha^{-1} Guinea grass green manure. Plot size was 5 m × 3 m with four rows, each 5 m long and spaced 0.5 m apart. These green manure rates were equivalent to 7.5, 15, 22.5 and 30 kg/plot respectively. The Guinea grass green manure was harvested near the site, weighed fresh, and applied to the plots by placing and constructing ridges over it. The NPK fertilizer was split applied by ring method to the appropriate plots, one-half at two weeks after planting (W.A.P.) and the other half, at the onset of tasseling.

Planting material, planting, spacing, data collection and harvesting

The variety *Z. mays* L. (cv. DMR-ESR Yellow) obtained from the Sierra Leone Institute of Agricultural Research (SLARI), was the planting material. Spacing was 50 cm × 75 cm and 25 cm from edge of each plot. Three seeds were planted per hill on 11th June, 2018, at a depth of 2 cm, 50 cm apart in rows, and 10 days after green manure application and then thinned to two per stand, 10 days after germination. This resulted in a maize population of 80 per plot, and 53,333 plants per hectare. The plots were entirely rain-fed and hand-weeded at 20, 40 and 60 days after planting. Data were collected from six tagged plants in the two middle rows of each plot excluding the end plants on the parameters of plant height, stem girth, number of leaves, leaf area, dry root weight and grain yield. Plant height, stem girth (20 cm above ground), number of leaves, and leaf area were measured on the 30th, 40th, 50th and 60th days after planting.

Plant height: Plant height of each tagged plant was measured from the ground level to the node of the last leaf.

Stem girth: Stem girth of each tagged plant was measured using a tape rule, 30 cm from ground level.

Leaf area: The area of the 5th leaf on a tagged plant was measured by multiplying leaf length and breadth (breadth at mid-way along length of leaf) and multiplying with a constant of 0.75.

Dry root weight: The six tagged plants of each plot were carefully uprooted after harvesting, shoots removed, and the roots washed and oven-dried at 60°C to 15% moisture content and weighed.

Grain yield: The maize was harvested at physiological maturity on 18th September, 2018, about 90 days after planting. Thirty plants in the two middle rows of each plot (excluding the end plants) were harvested. The harvested ears were air-dried for fifteen days, shelled, and seeds oven-dried at 60°C to 12% moisture content and weighed.

The grain yield from each plot was calculated per hectare by multiplication with a correction factor and the mean value presented for statistical analysis.

Statistical analysis

The General Linear Models Procedure of the Statistics Analysis for Microsoft Windows Release 15:37, Monday, June 15, 1998 (SAS Institute) was used to detect differences between treatments for all variables. The treatment means were subjected to Duncan's Multiple Range Test to specify the particular pairs of treatments that differ significantly.

Results and Discussion

Pre-cropping soil properties

Before planting, soil samples (0-20 cm deep) were collected in three locations in each replication with a soil-sampling augur. They were mixed to form one composite soil sample which was taken to the Sierra Leone Agricultural Research Institute (SLARI) laboratory and analyzed as follows: 83% sand, 11% clay, 6% silt, texture (loamy sand), 1.84 organic carbon, 8.56 ppm available P, CEC=9.82 meg/100 g, pH (H2O)=3.9, 0.08 cmol/kg exchangeable K, 0.14 cmol/kg exch. Ca, 0.11 cmol/kg exch. Mg, 1.6 cmol/kg exch. Al, 2.4 cmol/kg exch. Acidity.

The fertilizer treatments were highly significant for plant height, stem girth, number of leaves, leaf area, dry root weight and grain yield. Maize grain yield progressively increased from the 5 t ha^{-1} to the 15 t ha^{-1} Guinea grass green manure rate, but declined at 20 t ha^{-1} green manure rate. There was a significant increase in grain yield with rate of 15 t ha^{-1} green manure over the 5 t ha^{-1} green manure, NPK fertilizer and 'no fertilizer' respectively. Compared with 'no fertilizer', there were increases in grain yield of 76%, 109%, and 174% with manure rates of 5, 10 and 15 t ha^{-1} green manure rates, respectively. There was no significant difference in plant height between the 'No fertilizer' and 200 kg ha^{-1} NPK 15:15:15 treatments, as well as between 15 t ha^{-1} Guinea grass green manure and 20 t ha^{-1} Guinea grass green manure, which were highest in plant height. Improved plant height and leaf area in maize plants resulting from the application of organic manures was noticed [11,12]. Similarly, considerable increases in fresh and dry weights of roots and shoots resulted from the application of organic manures [13]. This improved plant growth by addition of green manure may have resulted improved mineral nutrition of plants by the slow release of minerals in the manure in the heavily leaching soils, where the applied NPK fertilizer, on the other hand may have been easily leached; and the second application could have only benefited nitrogen remobilization to grains and less plant growth (height and leaf area).

The 15 t ha^{-1} manure treatment with a plant height of 61.2 cm, stem girth of 5.5 cm^2, leaf area of 373.2 cm^2, and grain yield of 1.705 t ha^{-1}

produced better maize performance than any other treatment. The NPK fertilizer rate gave the lowest increase in grain yield compared with the manure rates (Table 1). This result is consistent with findings of studies with rice which indicates that green manures increase rice grain yield and Lahai study shows that maize grain yield increases with increase in the rate of manure [14]. This could be due to the fact that organic manures play a major role in maintaining soil fertility by adding nutrients such as N, P, and K to the soil. They are also a major source of food for soil organisms which help decompose organic matter. They improve soil physical properties such as promoting soil water and nutrient retention capacities and reducing soil bulk density [15].

There were significant increases in stem diameter, leaf area and grain yield at 5 t ha^{-1} and 15 t ha^{-1} manure rates over the control and fertilizer treatments but declined at 20 t ha^{-1} manure rate. This could be due to the fact that chemical fertilizers added to the soil without manure were easily leached and eroded due to high tropical rainfall, reducing the expected crop yield increase [16]. The decline phenomenon could be explained that the pH 3.89 of the experimental site increased beyond the optimum pH 6-7 for the best performance of maize with increase in manure rate beyond 15 t ha^{-1} [17]. The increase in manure rate produces alkalis, which increase soil pH [18].

Treatment	**Plant height (cm)**	**Stem girth (cm^2)**	**Number of leaves**	**Leaf area cm^2**	**Dry root weight (g)**	**Grain yield (t ha^{-1})**
No fertilizer	37.4^c	4.4^c	8.5^c	253.2^c	2.7^b	0.623^c
200 kg ha^{-1} NPK 15:15:15	36.8^c	4.7^{bc}	8.5^c	301.6^b	2.7^b	0.999^{bc}
5 t ha^{-1} Guinea grass green manure	50.9^{ab}	4.8^b	9.5^{ab}	317.4^b	4.9^a	1.097^{bc}
10 t ha^{-1} Guinea grass green manure	46.2^{bc}	4.7^{bc}	9.0^{bc}	289.7^{bc}	3.4^b	1.300^{ab}
15 t ha^{-1} Guinea grass green manure	61.2^a	5.5^a	10.0^a	373.2^a	3.6^a	1.705^a
20 t ha^{-1} Guinea grass green manure	42.2^a	4.9^b	8.7^c	297.7^{bc}	2.5^b	1.169^b
CV (%)	33.1	9.1	11.4	17.9	21.8	28.1
Note: Any two means within the same column having a common letter are not significantly different at the 5% level of significance using Duncan's Multiple Test Range						

Table 1: Growth and Yield Characteristics of Maize under Different Rates of Guinea Grass Green Manure.

Plant heights (days after planting) differed significantly among the various fertilizer treatments. The 15 t ha^{-1} green manure treatment produced the produced the greatest increase in plant height (61.2 cm) 50 DAP and the 0 t ha^{-1}, the least (37.4 cm) (Table 2). Compared with the 0 treatments (387%), there were plant height increases between the 30th and 50th DAP of 517, 531, 717, and 484% with the 5, 10, 15, and 20 t ha^{-1} manure treatments respectively.

The increase in plant height with the 200 kg ha^{-1} NPK fertilizer treatment between the 30th and 50th DAP was 482.5%; 95.5% greater than the increase in the 0 t ha^{-1} green manure treatment.

Treatment	**DAP**	**DAP**	**DAP**	**Treatment mean**
	30	**40**	**50**	
No fertilizer	15.9	18.9	77.4	37.4^c
200 kg ha^{-1} NPK 5:15:15	12.6	24.5	73.4	36.8^a
5 t ha^{-1} Guinea grass green manure	17.4	27.6	107.7	50.9^{ab}
10 t ha^{-1} Guinea grass green manure	15.3	26.9	96.5	46.2bc
15 t ha^{-1} Guinea grass green manure	16.1	35.9	131.5	61.2^a
20 t ha^{-1} Guinea grass green manure	14.8	26	86.5	42.4^{bc}
DAP	15.3^c	26.6^b	95.5^a	-
Note: Means in the same column or in the same row followed by the same letter are not significantly different at the 5% level of significance using Duncan's Multiple Test Range.				

Table 2: Maize Plant Height (cm) under Different Rates of Guinea Grass Green Manure.

There were no significant differences among treatments for days to 50% tasseling and days to 50% silking (Table 3). However, there was a significant difference between the 10 t ha^{-1} (6.2 days) and the 5 t ha^{-1} (4.5 days) green manure treatments.

Treatment	**Days to 50% tasseling**	**Days to 50% silking**	**Anthesis-silking interval**
No fertilizer	55.0^{ab}	61.3^a	6.3^b
200 kg ha^{-1} NPK 15:15:15	57.3^a	61.0^a	3.7^a
5 t ha^{-1} Elephant Grass Green Manure	53.8^a	58.3^b	4.5^a
10 t ha^{-1} Elephant Grass Green Manure	53.3^{ab}	60.5^a	6.2^{bc}
15 t ha^{-1} Elephant Grass Green Manure	53.8^a	57.8^a	4.0^a
20 t ha^{-1} Elephant Grass Green Manure	55.8^{ab}	59.8^a	4.0^a

CV (%)	3.7	4.6	3
Note: Treatment means in the same column followed do not differ significantly at the 5% level using Duncan's multiple Test Range.			

Table 3: Days to 50% Tasseling, Days 50% Silking, and Anthesis-Silking Interval under Different Rates of Guinea Grass Green Manure.

Conclusion

There were increases in most yield components with increasing rates of application of Guinea grass green manure. The percent increases in grain yield, dry root weight, leaf area and stem girth with the NPK fertilizer treatment were lower than those with green manure treatments of 5, 15 and 20 t ha^{-1}.This suggests the suitability of Guinea grass as a green manure for the cultivation of maize. Guinea grass is one of the dominant grasses in Sierra Leone and has successfully invaded much of the arable land. Farmers often incorporate it into the soil as green manure during seedbed construction for maize and tuber crops production. It is a cheap source of nutrients for plant growth and production. For this experiment, the 15 t ha^{-1} Guinea grass green manure rate seems to be the optimum. However, it is recommended that the integration of green manure and NPK fertilizer could give better maize performance.

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