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Effect of Tillage Methods and Foliar Fertilization (*Boost Extra*™) on Soil Physical Properties, Weed Dry Matter and Grain Yield of Sorghum in Ejiba, Kogi State, Nigeria

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Abstract

An experiment was carried out for two consecutive growing seasons (2012 and 2013) at the Research Site of the Lower Niger River Basin Development Authority, Ejiba, Nigeria, to examine the response of sorghum to tillage methods and foliar fertilizer (*Boost Extra*™) application. A split plot experiment was laid out in a Randomized Complete Block Design (RCBD) with three replicates to randomize the tillage methods (main plots) and foliar fertilizer application (sub-plots), respectively. The experiment comprised of three tillage methods: No Tillage (NT), Manual Tillage (MT) and convectional tillage (Ploughing, Harrowing and Ridging, PHR) and three foliar fertilizer rates: 0, 2 and 4 liters of foliar fertilizer per hectare. The parameters taken on soil physical properties and weed characters are soil moisture content (%), soil temperature (°C), weed species and weed dry weight (g). Growth and yield parameters taken are: average plant height (cm), stem girth (cm), leaf area (m^2), days to 50% flowering, root dry weight (g), shoot dry weight (g), weight of 1000 seeds and grain yield per land area. Weeds were identified and harvested, and their dry weights were taken and recorded. Data were also collected from ten randomly selected plants in each plot. The data were statistically analyzed using GENSTAT. The analysis of variance (ANOVA) was carried out to find out the significance of variation among the treatments while the significant differences between mean treatments were separated using Duncan's Multiple Range Test (DMRT) at 5% level of probability. The results obtained from this study indicated that tillage methods and foliar fertilizer application significantly affected growth and yield parameters of sorghum, consequently the

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yield per unit area. The results also indicated that "Manually Tilled" seedbed (MT) improved soil physical properties better than either plots with PHR or No Till plots in the study area. Foliar fertilizer application at 2 l/ha performed best in terms of growth and yield. It is therefore recommended that manual tillage should be used as a method of seedbed preparation for sorghum production. However, better and stable grain yield of sorghum could be obtained with the practice of manual tillage (MT) in combination with foliar fertilization at rate of 2 litres/ha. It is recommended that different tillage methods should be combined with foliar fertilizer application for higher grain yield in the study area.

Keywords

Tillage Method, Foliar Fertilizer, Fertilizer, Sorghum, Weed, Manual, Yield

1. Introduction

Sorghum is a cereal indigenous to Africa and accounts for 43% of all major food staples produced in sub-Sahara Africa [1]. It is drought-resistant [2] and many species are grown in zones characterized by low and erratic precipitation that is partly responsible for poor yield [3]. The average yield could be as low as 500 - 800 kg/ha [4]. Many factors are responsible for the low grain yield in sorghum [5]. Appropriate tillage method is considered one of the factors for increasing the yield of sorghum per unit area. According to [6], the primary aims of tillage are: to control weeds, manage surface trash, provide aeration, prepare good seed beds, shape or level the soil, improve physical conditions of the soil, incorporate fertilizers, break hard pans and allow better water and air infiltration. Soil compaction is generally defined as an increase of the natural density of soil at a particular depth [7]. The density increase translates into less pore space, less water available to plants, slower water transport and decreased roots. The roots can penetrate the compacted zone as it seeks out water and nutrients, but the formation of lateral roots can reduce [8]. Similarly, bulk density increase due to compaction can serve to retard or divert the flow of water, resulting in pond formation or excessive runoff. Soil moisture is the source of water for plant use, particularly in rain-fed agriculture [9]. Soil moisture is highly critical in ensuring good and uniform seed germination and seedling emergence [10], crop growth and yield.

Soil application is the most common method to supply essential nutrients to plants and applied nutrients are absorbed from the soil by plant roots. However, higher plants can also absorb mineral nutrients applied as foliar sprays in appropriate concentrations. Foliar fertilizer application is one of the most effective methods to correct nutritional disorder and to supplement the plant nutrients for more efficient nutrient utilization [11]. Furthermore, interest in foliar sprays has increased because the development of high concentration soluble fertilizers and the increasing use of machinery for spraying fungicides, herbicides and insecticides, and overhead irrigation further facilitate the application of nutrients to crops in the form of liquid sprays. The objective of this research is to examine the response of sorghum to tillage methods and foliar fertilizer application, Boost Extra^{TM}, in the study area.

2. Materials and Methods

2.1. Experimental Site

The experiment was carried out for two consecutive growing seasons (2012 and 2013) at the Research Site of the Lower Niger River Basin Development Authority, Ejiba, Kogi State of Nigeria (Lat. 8˚18'N and Long. 50˚39'E). The site is 1000 m above sea level, in the southern Guinea savanna agro-ecological zone of Nigeria, having hot, dry seasons and cool, wet seasons. The rainfall spans April to November and peaks in June while the dry season extends from December to March. The mean annual rainfall is 1570 mm per annum with an annual temperature range of 18˚C - 32˚C and mean relative humidity (RH) of 60% (Meteorological Data, 2011). The major soil order within the experimental site is Gleysol [12] [13].

The experiment was sited within a 14 ha agricultural field that has been mechanically tilled and cropped with tropical arable crops (maize, cowpea, sorghum, garden egg, okra, tomato and cassava) continuously for over

twenty years.

2.2. Determination of Soil Physical Properties.

Soil moisture content was taken at 30 and 60 days after planting. Five undisturbed samples were collected at 0 - 15 cm depth from each plot using core samplers and were used for the determination of gravitational moisture content after oven drying at 100˚C for 24 hours. Soil temperature was determined at 15.00 hours (3 pm Nigerian time) with a soil thermometer inserted to 5 cm depth. Five readings were made per plot at each weekly determination and the average values recorded.

2.3. Soil Sampling and Analysis

In order to determine some chemical properties of the soil before the treatments were applied, 20 random soil samples were collected from the field and bulked to for a composite sample. The sample was air-dried and sieved with a 2 mm sieve and analyzed in the laboratory for N, P, K, pH and Organic carbon. Total N (%) was determined by the macro-Kjeldahl method [14]. Available P (ppm) was determined using the Bray I method according to Olsen [15]. Soil pH values were obtained by using a HI9813-5 portable pH/EC/TDS/˚C meter (HANNA instruments, Romania, 2002). Soil organic carbon was determined by the Walkley-Black procedure [16].

2.4. Field Methods

A split plot experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications to randomize the tillage methods and foliar (Boost Extra) application in the main and sub-plots, respectively. The experiment comprised of three tillage methods, viz: No Tillage (NT), Manual Tillage (MT) and convectional tillage (Plough + Harrow + Ridge, PHR) and three foliar fertilizer rates: No Foliar, 2 and 4 liters/ha foliar fertilizer. The treatments were applied on the same plots in 2012 and 2013 growing seasons. Each plot was 10.0 m long and 5.0 m wide. A buffer zone of 4.0 m spacing was provided between plots. In both growing seasons, one of the most commercial acceptable varieties of sorghum (cv. F1) was planted on 25th April manually at a spacing of 25 cm by 50 cm. A basal dose of phosphorus at 90 kg·ha^{-1} and nitrogen at 60 kg·N·ha^{-1} was applied to all plots at the time of sowing. Foliar spray of Boost Extra at 0, 100 and 200 ml in 20 litres of water and a surfactant (Tween-80) was mixed at (1 ml/liter) with the solution to increase adhesion of solution on plant foliage. The required quantity of foliar spray of Boost Extra was applied to the crop at 30, 60and 90days after planting (DAP). The control treatment was sprayed with ordinary water. During the growing seasons, insecticides and fungicides were applied according to general local practices and recommendations. All other necessary operations except those under study were kept normal and uniform for all the treatments.

2.5. Weed Characters

At 30 and 60 DAP, weed samples were collected from two 50 cm × 50 cm randomly laid quadrants in each plot. The weeds were identified up to species level, cut at the soil surface, oven-dried at 80˚C for 48 hours and weighed to determine the dry matter (DM) yield.

2.6. Growth and Yield Parameters

Root and shoot biomass, plant height, days to 50% flowering, grain yield and yield components in sorghum were monitored. Five plants were randomly sampled from 2 m^2 area at the center of each plot at 16 WAP and oven-dried at 80˚C for 48 hours for the determination of root and shoot dry matter yields. For root biomass determination, a cubic coring tool (10 × 10 × 10 cm) was drilled into the soil to a depth of 40 cm within the circumference of 5 sampled plants per plot. The excavated roots from the soil samples were put in 2 mm sieves and were gently washed free of soil in the laboratory using moderate jets of water. The values of plant height, leaf area, number of leaves per plant and stem girth were determined at 16 WAP. Leaf area was calculated as number of terminal leaflets (N) × 2.7 × 1/37 cm^2 [17]. Ten sorghum plants were harvested per plot at maturity for yield components determination. The components were: weight of panicle per plant (g), length of panicle (cm), seed weight per plant (g) and 1000 seed weight (g). Afterwards, the entire plots were separately harvested, threshed and grains were air-dried and weighed.

2.7. Statistical Analysis

Data were statistically analyzed using GENSTAT. The analysis of variance (ANOVA) was performed to find out the significance of variation among the treatments while the significant means were separated using Duncan's Multiple Range Test (DMRT) at 5% level of probability.

3. Results and Discussion

Table 1 presents the mean of the meteorological variables at the study site during sorghum growth in the respective seasons of 2012 and 2013. The properties of the soil at the site of the experiment are presented in **Table 2**. The soils are predominantly sandy, slightly acidic with relatively high bulk density. The organic matter, total nitrogen, available phosphorus, exchangeable potassium and calcium were low. Application of foliar fertilizer is expected to benefit the crop.

3.1. Tillage Methods and Foliar Application Effect on Weed Density

Different weed species, both grass weeds and broad-leaf weeds, were observed in the field during the experiment. The dry weight of grass weeds and broad-leaf weeds were significantly (P = 0.05) higher under no-tillage (NT) treatment. In contrast, significantly lower amounts of dry weight of grass and broad-leaf weeds were observed in the plots under MT and PHR treatments (**Table 3**). This may be due to the ability of tillage implements to turn over and cover crop residues and weeds. These results are in line with the results of [18]-[20] who also observed that reduced tillage treatment (no-tillage) had significantly higher grass and broad leaf weeds than the conventional tillage (PHR) treatment. This high weed density must have competed with sorghum for water and plant nutrients. Weeds that quickly emerge can hinder the growth of sorghum crop. [19] [21] reported that severe weed population pressure reduced overall crop yield in conventional tillage system. Plots to which Boost Extra was applied had higher weed dry weight than No Foliar (zero application) plots. This could be due to foliar nutrient drifts to weeds during treatment application.

Table 1. Mean weather factors for the years 2012 and 2013 cropping seasons.

	March	April	May	June	July	August	Sept.	October
R/F (mm)	6.4	49.6	172.0	189.4	244	231	211	154
Temp (˚C)	33.1	33.3	32.3	31.8	30.8	28.6	30.6	30.8
R/H (%)	48	52	66	74	76	80	67	60
Sun-shine/day	9.8	10.03	9.45	9.47	9.26	8.77	9.23	9.8
No of rainy day	01	03	14	12	14	20	13	11

Table 2. Chemical properties of the soil of the experimental field before the experiment.

Soil properties	2012	2013	Mean
Sand (%)	61.84	62.4	62.1
Silt (%)	26.15	24.8	25.4
Clay (%)	12.01	12.8	12.5
Organic manure (%)	2.13	2.48	2.31
Soil pH	5.80	5.90	5.85
Total N (%)	0.13	0,17	0.15
Ca (cmol/kg)	2.16	2.67	2.42
M (cmol/kg)	3.02	2.78	2.90
K (cmol/kg)	1.56	1.48	1.52
Na (cmol/kg)	0.03	0.07	0.05
P (mg/kg)	2.48	3.46	2.97

Table 3. Mean effects of tillage methods and foliar fertilizer on weed species and biomass.

Treatments	30 days		60 days		90 days	
Tillage methods	Weed species	Weed dry weight (g)	Weed species	Weed dry weight (g)	Weed species	Weed dry weight (g)
NT	17a	360a	19a	960a	21a	1115a
MT	16a	186b	17b	464b	17ab	780b
PHR	14b	53c	14c	316c	14b	743b
LSD	1.23	54	1.56	136.4	5.6	143.9
Foliar fertilizer						
NF	17a	68a	17a	186b	17a	584b
2 l/haF	17a	66ab	17a	214a	17a	601a
4 l/haF	17a	64b	17a	268a	17a	603a
LSD	ns	2.43	ns	62.8	ns	11.3

In a column, figures bearing same letter (s) do not differ significantly at 5% level of probability by DMRT.

3.2. Effect of Tillage Methods and Foliar Fertilization on Bulk Density and Soil Moisture

Soil bulk density is probably the most frequently measured soil quality parameter in tillage experiments [22]. The effect of the different tillage practices on bulk density in the 0 - 15 cm is shown in **Table 4**. Over the course of the study, tillage practices significantly affected soil dry bulk density. The No Tillage treatment recorded the highest bulk density at 30, 60 and 90 DAP (1.54, 1.60 and 1.62 g/cm^3 respectively) significantly higher than that of the PHR followed by MT treatments. This is similar to the report of [23]. The Plough + harrow + ridge treatment produced higher bulk density compared to manual tillage. These findings widely agree with the results obtained by [24] working under Ferric Luvisol in the northern Guinea savannah zone of Ghana. Also, [25], working under Ferric Luvisol in the rainforest zone at Akure in Nigeria reported similar results.

Tillage treatments showed significant increase in moisture content over time at 30, 60 and 90 DAP (**Table 4**). Manually tilled (MT) plots had the highest moisture contents (19.3%, 20.3% and 22.6% at 30, 60 and 90 DAP, respectively). This agrees with the findings of [23] who reported the highest moisture contents in Manually Tilled soil. In contrast, [25] and [26] observed higher soil moisture contents in No Tillage plots, compared with that of disc-ploughed followed by disc-harrowed plots.

Foliar fertilizer application had no significant effect on soil physical properties in this investigation (**Table 4**).

3.3. Effect of Tillage Methods and Foliar Fertilization on Growth and Yield Components of Sorghum

The tillage methods influenced growth and yield parameters of sorghum in this study (**Table 5**). The highest values of plant height (257 cm) and leaf area (1.5 m^2) were obtained from Manual Tillage plots which was significantly higher (P = 0.05) than values obtained in plots with PHR or NT treatments (**Table 5**). The result was in line [27] who obtained highest values of growth parameters (plant height, leaf area and stem girth) from manually tilled plots which were significantly higher (P = 0.05) than values obtained with ploughing plus harrowing.

Records of 50% flowering showed that the highest values under manual tillage but this was not significantly higher (P = 0.05) than plots with NT and PHR treated plants. Plough + harrow + ridge plots (PHR) produced the highest grain yield (0.78 t/ha) and 1000 seed weight (21.37 g, **Table 6**). This was closely followed by MT plots (0.74 t/ha and 20.3 g, respectively). In all tillage methods, plats on NT plots produced the least values of growth and yield characters considered in this work (**Table 6**).

[28] worked on the response of soil properties and Sorghum to tillage and applied poultry manure in the forest-savanna transition zone of Nigeria. He observed that manually tilled soil produced the highest values of growth and yield components of Sorghum and he attributed this to favorable soil conditions resulting from minimal disturbance of the land. Lower performance of plough + harrow + ridge plots in terms of growth and yield characters could be due to deterioration of soil quality resulting from passage of implement [29] [30].

Table 4. Effect of tillage methods and foliar fertilizer on soil physical properties (mean of 2012 and 2013).

Treatments	Bulk density			Moisture content		
Tillage methods	30 days	60 days	90 days	30 days	60 days	90 days
NT	1.54a	1.60a	1.62a	16.3b	18.2b	19.3b
MT	1.21c	1.26c	1.31b	19.3a	20.3a	22.6a
PHR	1.38b	1.43b	1.53a	16.5b	18.4b	19.4b
LSD	0.09	0.11	0.10	0.05	0.06	0.06
Foliar fertilizer						
NF	1.33a	1.34a	1.33a	16.8a	17.3a	16.3a
2 l/haF	1.36a	1.33a	1.34a	17.4a	16.9a	16.6a
4 l/haF	1.31a	1.37a	1.32a	16.9a	17.2a	15.9a
LSD	ns	ns	ns	Ns	ns	Ns

In a column, figures bearing same letter (s) do not differ significantly at 5% level of probability by DMRT.

Table 5. Effect of tillage methods and foliar fertilizer on growth characters of sorghum.

Tillage methods	Plant height (cm)		Stem girth (cm)		Leaf area (m^2)		Days to 50% flowering	
	2012	2013	2012	2013	2012	2013	2012	2013
NT	126b	186b	2.41b	2.11a	1.13b	1.17b	119a	119a
MT	246a	267a	3.60a	3.54b	1.48a	1.51a	118a	119a
PHR	253a	271a	3.68a	3.61b	1.46a	1.54a	118a	118a
LSD	36	17	44	0.3	0.04	0.09	ns	Ns
Foliar fertilizer								
NF	124b	153b	2.38b	2.41b	1.11c	1.19b	119a	118a
2 l/haF	238a	278a	3.91a	3.98a	1.29b	1.49a	118a	118a
4 l/haF	243a	266a	3.84a	4.02a	1.36a	1.38a	118a	119a
LSD	19	14	0.04	0.06	0.04	0.13	ns	Ns

In a column, figures bearing same letter (s) do not differ significantly at 5% level of probability by DMRT.

Table 6. Effect of tillage methods and foliar fertilizer on yield characters of sorghum.

Tillage methods	Root dry weight (g)		Shoot dry weight (g)		Weight of 1000 grains (g)		Grain yield (t/ha)	
	2012	2013	2012	2013	2012	2013	2012	2013
NT	50.6a	48.6b	19.38b	19.4ab	18.5b	17.5b	0.64b	0.69c
MT	47.6c	48.3b	19.42b	18.9b	21.4a	20.0a	0.75a	0.72b
PHR	49.2b	50.3a	20.12a	20.6a	22.2a	20.4a	0.74a	0.81a
LSD	1.2	1.4	0.06	0.6	1.6	1.2	0.03	0.02
Foliar fertilizer								
NF	43.8c	47.5a	18.3b	17.4b	16.9c	18.4b	0.54b	0.64b
2 l/haF	47.3b	43.9b	19.4b	18.6a	20.8a	19.3a	0.66a	0.76a
4 l/haF	51.3a	44.6b	22.4a	18.7a	19.8b	18.4b	0.60a	0.74a
LSD	2.44	0.13	0.12	0.04	0.03	0.03	0.05	0.04

In a column, figures bearing same letter (s) do not differ significantly at 5% level of probability by DMRT.

No Tillage plots recorded the least plant height, leaf area, stem girth, grain weight and grain yield in this study. Foliar fertilizer application improved significantly (P = 0.05) the growth and yield components of sorghum over unfertilized plots (**Table 6**). The application of foliar reduced the number of days to attain 50% flowering by one day, but significantly increased (P = 0.05) plant height and stem girth over the unfertilized plants (**Table 5**).

[31] reported increase in growth and biological yield of wheat by foliar application of zinc. In this work, the grain yield also increased significantly with foliar application of Boost Extra (**Table 5**). Maximum grain yield was produced by 4 l/ha Boost Extra spray, while minimum grain yield was produced in No Foliar application plots. All spray application levels were found beneficial as compared to control (water spray) on sorghum. The results are in conformity with [32] who reported increased straw yield with foliar application of N. [33] concluded that a multi-component foliar fertilizer containing N significantly increased the yield of cabbage. The high efficiency of Boost Extra application observed in this study is in agreement with the findings of [34] for onion and [35] for "Faba" bean.

4. Conclusion

Tillage methods and foliar fertilizer application affected growth and yield parameters of sorghum significantly per unit land area. The results also indicated that seedbed prepared manually improved soil physical properties better than plots that were ploughed, harrowed and ridged or No Till plots. Foliar fertilizer application at 2 l/ha performed best in terms of growth and yield characters of sorghum in the study area.

5. Recommendations

Based on the results obtained in this study, it is recommended that manual tillage should be used as method of seedbed preparation for sorghum production in the study area. However, higher grain yield of sorghum could be obtained with the practice of manual tillage combined with foliar fertilizer application (Boost Extra) at rate of 2 l/ha. There is the need to carry out further studies, especially cost benefit analysis and multi-locational trials in future studies.

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