Productivity of irrigated maize as influenced by amendments and weed management strategies in the semi-arid Savanna region of Nigeria

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Abstract

Maize production is affected by nutrition, biotic and climatic variables. To evaluate the effect of these, a field experiment was conducted in the dry seasons of 2015 and 2016 at the Teaching and Research Farm of Faculty of Agriculture, Bayero University, Kano, Nigeria. The treatments included three irrigation intervals, three weeding methods and seven levels of soil amendments. The experiments were laid out in split-split plot design replicated three times. The results revealed that soil amendments had positive effect on soil properties. Irrigation interval significantly influenced both weed growth and maize performance. Irrigating maize at 3 days intervals with combined application of biochar at @ 3.75 t per ha, compost @ 1.25 t per ha and NPK @ 60:30:30 kg per ha resulted in higher grain yields (2780 and 3990 kg per ha) in 2015 and 2016 respectively. Herbicide applications with biochar @ 3.75 t per ha, compost @ 1.25 kg per ha and NPK @ 60:30:30 kg per ha recorded higher grain yields (2688 kg per ha in 2015 and 3100 kg per hain2016). Combined application of biochar at @ 3.75 t per ha, compost @ 1.25 t per ha and NPK @ 60:30:30 kg per ha with irrigation at three days interval improved soil properties and recorded the highest grain yield and can be recommended in the study area.

Key words: Irrigation, Maize, Soil amendment, Weed, Yield.

Introduction

Sudano-Sahelian savanna region, the dryland habitat of Nigeria plays a dominant role in the agricultural development of the country. The region is important for the production of major food crops. Among the staple food crops, cereals such as maize, rice, sorghum and millet have risen to a position of pre-eminence (UNEP, 2005). In Nigeria, maize production stood at 10.5 million metric tons in 2016, with an average yield of 1.8 tons per hectare (FAO, 2017). A combination of climatic variability, biotic constraints and declining soil fertility has continuously hampered the production of important crops including maize across many Sub-Saharan African (SSA) countries. Maize has been more prominently affected by these factors because of its sensitivity to both soil and bio-climatic constraints (Zerihun and Haile, 2017). In Nigeria, maize is predominantly grown in the rainy season with an average yield of 1.64 t ha^{-1}(NAERLS, 2010). The crop is sparsely grown under irrigation but the yields averaged 2.9 t ha^{-1}(Nosiru and Odusina, 2008). Liverpool-Tasie et al. (2017) reported an improved maize grain yield with fertilizer application, but observed hindrance in use due to the higher cost which necessitated supplementation with organic soil amendments. Based on agronomic and environmental advantages, Mutezo (2013) suggested the use of materials such as biochar over Farm Yard Manure (FYM) in maize production. Weed problems are high in maize and there is little published information on the effect of biochar and other organic amendments on weeds. In this

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background the present experiment was undertaken with the aim of exploring alternative maize agronomy for the region. The specific objective of the research was to evaluate how irrigation intervals, use of amendments and weed management methods improved the productivity of maize in this vulnerable region of the country where agricultural innovations are needed.

Material and methods

The study was conducted in two seasons (dry seasons of 2015 and 2016) at the Research Farm of the Faculty of Agriculture, Bayero University, Kano, Nigeria. Kano lies between latitude 10 –13°N and longitude 8 – 9° E and falls within the dry, sub-humid agro-ecological zone of Nigeria with mean annual rainfall range of 600-726 mm, potential evapotranspiration of 1700-1800 mm per annum and mean annual temperature of 28°C (Adamu et al., 2014).

The treatments consisted of three factors: irrigation intervals, weeding methods and soil amendments arranged in a split-split plot design replicated three times. Irrigation regimes were assigned to main plot, with weeding method as sub-plot and soil amendment as sub-sub-plot factor. Irrigation was at three (I_1), five (I_2) and seven (I_3) days interval. It was done in the late evening to field capacity at the rate of 430 L per plot (13.5m^2). The three weeding methods employed were, Primextra @ 1.5 kg a.i. per ha followed by post emergence application of Nicosulfuron (at 6 weeks after sowing) @ 0.045 kg a.i.ha^{-1}(W_1), two manual hoe weedings at three and six weeks after sowing (WAS) (W_2) and weedy check (W_0) as control. The rate of organic amendment was decided based on perceived potential adoption by resource-poor farmers and relative successes recorded by previous researches (Major, 2010). The treatments involving the amendments (organic and inorganic) and their combinations were as follows:

S_1: Biochar @ 5 t per ha
S_2: Compost @ 5 t per ha
S_3: NPK @ 120:60:60 kg per ha
S_4: Biochar @ 5 t per ha + NPK @ 60:30:30 kg per ha
S_5: Compost @ 5 t per ha+ NPK @ 60:30:30 kg per ha
S_6: Biochar @ 3.75 t per ha + Compost @ 1.25 t per ha + NPK @ 60:30:30kg per ha
S_0: Control (without any amendment)

The gross plot (13.5m^2) consisted of six ridges of three meters length and the net plot size was 4.5 m^2. The inter and intra row spacings were 0.75m and 0.25m respectively. The maize variety grown was Sammaz 27. The land was cleared using hoe, ploughed and harrowed to a fine tilth, levelled and marked into the appropriate plot sizes as described in the experimental design. Organic amendments were applied in the soil a week before planting and worked into the soil. Maize was sown at the rate of two seeds per hole and were later thinned to a single plant, two WAS. Irrigation was done by surface water application late in the evening to field capacity (with the amount of water quantified as 430 L per plot). Half N and all of P and K fertilizers were applied at two weeks after sowing (WAS) using the nutrient source NPK,15:15:15, and the remaining half N as urea (46%N), at four WAS. Weeding was done as per the treatments fixed.

The organic amendment, compost and biochar were prepared at the site for use in the experiment. Fresh compost was produced in the successive years of the experiment in compost pens by mixing the anaerobic digestate (AD) solids and leachate obtained by anaerobic digestion of municipal solid waste (MSW) with grasses (dried and fresh) and poultry litter in the ratio of 1:4:1 respectively. The setups were sufficiently moistened by applying water approximately @ one litre per 5 kg material at an interval of five to seven days after the first 10 days in the absence of intervening rainfall. Complete turnings were done at an interval of two weeks and the set up was maintained for two months. The harvested material was allowed to cure for one week under shade and bagged in polythene bags before application. Biochar was produced in a fabricated metallic biochar kiln fitted with an inner cylindrical, airtight combustion chamber and an outer heater. Dried maize cobs were filled up to three fourth of the kiln's volume and heated to 400°C for three and a half hours. The system was allowed to cool overnight before evacuation to prevent re-ignition. The biochar was stored in polythene bags.

Five soil samples from field experiment were collected to the depth of 20 cm using an auger in 'M' shape zigzag pattern before and after the experiment at harvest, to evaluate impact of amendments on soil properties in each of the respective years. Samples were air dried, gently crushed and sieved through a two mm sieve mesh. Compost and biochar were characterized before application. The volatile matter, resident matter, porosity, pH and CEC of biochar were determined by the methods of McLaughlin et al.(2009). pH of compost and soil were determined in 1:2.5 material/ soil : water mixture with a pH meter; bulk density in all materials were determined by gravimetric method; N by micro-Kjheldal technique, organic carbon (OC) by dichromate wet oxidation method and CEC in soil and compost by neutral ammonium acetate saturation method. Neutral ammonium acetate was used in the extraction of exchangeable bases in all materials (Anderson and Ingram, 1993). $Ca^{2+}$and Mg^{2+} were read using Atomic Absorption Spectrophotometer (Buck Scientific Model 210 VGP), while Na^{+} and K^{+} were read using flame photometer (JenwayPFP7). Soil available P was extracted by the Bray1 method and determined colorimetrically (Jaiswal, 2004).

Data were collected on weed cover score according to Lado et al. (2015) and weed dry weight at physiological maturity (of maize). The observations recorded included number of productive ears per plant, cob weight per ha and grain yield at 12 per cent moisture content. Analysis of variance (ANOVA) was done using Genstat 17th edition and significant treatment means were separated using HSD Tukey's.

Results and discussion

The properties of the organic soil amendments used are given in Table1. The results revealed that both materials were relatively light and porous. These two properties may affect water and nutrient retention in treated soils (Liu et al., 2012).The pH of both materials was close to neutral with compost being slightly more alkaline (7.57) than the biochar (6.55). These ranges are favorable for use in most arable soils and suitable for most crops (USCC, 2011). There was a relatively higher N (12.8%) content in compost than in biochar (10.1%) due to the material composition and the production processes of each. Biochar contained more recalcitrant matter and organic carbon (753 g per kg) which made it a better potential material for carbon sequestration. Biochar, according to Schimmelpfennig and Glaser (2012), is relatively stable against microbial decomposition as a consequence of its intrinsic recalcitrance, mainly due to aromatic carbon ring structures being an obstacle for microbial decomposition.

Table 1. Physical and chemical properties of the biochar and compost used

Characteristics	Biochar	Compost	Unit
Physical			
Bulk Density (BD)	0.21	0.31	gcm^{-3}
Particle Density (PD)	0.68	2.52	gcm^{-3}
Porosity	87.54	69.09	%
Moisture Content (MC)	1.01	26.28	%
Mobile matter (MM)	15.50	18.00	%
Fixed Matter (FM)	82.50	52.50	%
Chemical properties			
pH	6.55	7.57	
EC	0.37	3.67	$dS\ m^{-3}$
CEC	18.70	23.07	$cmol_+ kg^{-1}$
Organic carbon (OC)	753.00	288.00	$g\ kg^{-1}$
Total Nitrogen (TN)	10.10	12.8	$g\ kg^{-1}$
Total P	24.40	34.9	$mgkg^{-1}$
Total K	16.40	21.3	$cmol_+ kg^{-1}$
Exchangeable Ca	0.50	0.50	$cmol_+ kg^{-1}$
Exchangeable Mg	1.25	1.21	$cmol_+ kg^{-1}$
Exchangeable K	0.897	1.077	$cmol_+ kg^{-1}$
Exchangeable Na	0.012	0.019	$cmol_+ kg^{-1}$

Table 2. Effect of soil amendments, irrigation intervals and weeding method on weed cover and dry weight of maize in 2015 and 2016 dry season

Treatments	2015 season		2016 season	
	Weed cover score	Weed dry weight kg ha^{-1}	Weed cover Score	Weed dry weight kg ha^{-1}
Irrigation Regimes (I)				
3 days (I1)	2.35	4009[a]	2.35	4611[a]
5 days (I2)	1.82	3666[a]	1.82	4205[a]
7 days (I3)	1.77	2494[b]	1.77	2868[b]
Level of significance	0.165	0.042	0.183	0.001
SED	0.102	410.9	0.102	472.6
Weeding Methods (W)				
Herbicides (W1)	0.60[b]	1657[b]	0.70[b]	1906[b]
Manual (W2)	0.34[b]	1010[b]	0.44[b]	1161[b]
Weedy check (W0)	3.80[a]	7493[a]	4.80[a]	8671[a]
Level of significance	0.001	0.001	0.001	0.001
SED	0.172	642.7	0.182	739.1
Amendments (A)				
S1	1.95	3100	1.95	3566
S2	2.02	3874	2.03	4455
S3	2.08	3073	2.08	3534
S4	2.03	3183	2.03	3661
S5	1.86	3234	1.86	3702
S6	1.94	3661	1.94	4459
S0	1.98	3591	1.98	4210
SED	0.278	1001.3	0.278	1151.2
Level of significance	0.521	0.817	0.432	0.182
Interaction				
I*W	0.213	0.115	0.295	0.104
I*A	0.122	0.181	0.131	0.214
W* A	0.154	0.312	0.211	0.236
I* A *W	0.412	0.345	0.529	0.249

Means followed by the same letter in a column are not significantly different at 5% level of probability using HSD tukeys

Table 2 shows the effect of irrigation intervals, weeding methods and amendments on weed cover score and dry weight in both seasons. Irrigation interval had no significant effect on weed cover score but it significantly affected weed dry weight in 2015 ($p<0.042$) and 2016 ($p<0.001$) respectively. There was higher weed dry weights at three days interval irrigation (4009 kg per ha) and (4611 kg per ha) which were statistically similar to five days (3666 and 4205 kg per ha) but different from seven days (2494 and 2868 kg per ha) intervals in 2015 and 2016 seasons respectively. This indicated that weed dry weight was significantly low when irrigated at 7 days interval. Das (2011) had reported that weeds had a competitive advantage over crop under both stress and unstressed conditions.

Unweeded control plots recorded significantly higher weed cover score (3.80 and 4.80) and weed dry weights (7493 and 8671 kg per ha) in both seasons respectively compared to manual and herbicide applications. Weed management, both manual weeding and herbicide application, significantly reduced weed population and growth which conformed to the reports of Verma et al. (2017). Soil amendments had no significant effect on weed cover score ($p> 0.521$ and $p>0.43$) and weed dry weight ($p > 0.817$ and $p > 0.182$) in the

Table 3. Effect of soil amendments, irrigation intervals and weeding method on average number of productive ear per plant and cob yield of maize in 2015 and 2016 dry season

Treatments	2015 season		2016 season	
	Productive ear/plant	Cob yield kg/ha	Productive ears/ plant	Cob yield kg/ha
Irrigation Regimes (I)				
3 days (I_1)	0.98[a]	2175[a]	1.12[a]	2502[a]
5 days (I_2)	0.96[a]	1452[b]	0.86[b]	1670[b]
7 days (I_3)	0.75[b]	1294[b]	0.78[b]	1488[b]
Level of significance	0.001	0.022	0.002	0.011
SED	0.029	213.0	0.034	244.9
Weeding Methods (W)				
Herbicides (W_1)	0.88[a]	2015[a]	1.01[a]	2303[a]
Manual (W_2)	0.97[a]	2002[a]	1.06[a]	2328[a]
Weedy check (W_0)	0.59[b]	788[b]	0.67[b]	905[b]
Level of significance	0.001	0.001	0.001	0.001
SED	0.052	209.01	0.060	265.5
Soil Amendments (S)				
S_1	0.77[ab]	1298[ab]	0.86[bc]	1424[bc]
S_2	0.74[ab]	1204[ab]	0.85[ab]	1475[bc]
S_3	0.86[a]	1706[a]	0.99[a]	2282[a]
S_4	0.81[a]	2007[a]	0.93[ab]	2023[ab]
S_5	0.86[a]	2009[a]	0.96[ab]	2368[a]
S_6	0.88[a]	1908[a]	0.99[a]	2012[ab]
S_0	0.69[b]	902[b]	0.79[b]	1038[c]
SED	0.055	382.6	0.064	360.7
Level of significance	0.001	0.001	0.015	0.001
Interaction				
I*W	0.105	0.261	0.105	0.521
I*S	0.251	0.101	0.251	0.518
W* S	0.886	0.639	0.866	0.794
I* S *W	0.056	0.117	0.054	0.155

Means followed by the same letter in a column are not significantly different at 5% level of probability using HSD tukeys two respective seasons. This contradicted findings of Arif et al. (2012) who observed significant increase in weed growth with FYM application.

The effect of the treatments on maize productivity are presented are given in Table 3. Mean number of productive ears per plant was significantly influenced by irrigation interval in both seasons. Higher number of productive ears per plant in the respective seasons (0.98 and 1.12) was recorded with the three day irrigation interval and it was interpreted that as the interval was prolonged, maize productivity decreased due reduced dry matter accumulation under water stress. Further this reduction may be related to reduced leaf area index and declined lateral root formation as reported by Sangakkara et al. (2010).

Weeding method had significant effect on mean number of productive ears per plant in both seasons (Table 2).Manual hoe weeding consistently recorded higher productive ears per plant (0.97 and 1.06) but was statistically similar with herbicide application (0.88 and 1.01) in the respective seasons. Weedy check control plots produced the lowest number of productive ears per plant (0.59 and 0.67) in the respective seasons, which could be inferred as expected due to the severe competition between maize and weeds (Iderawin and Friday, 2018).

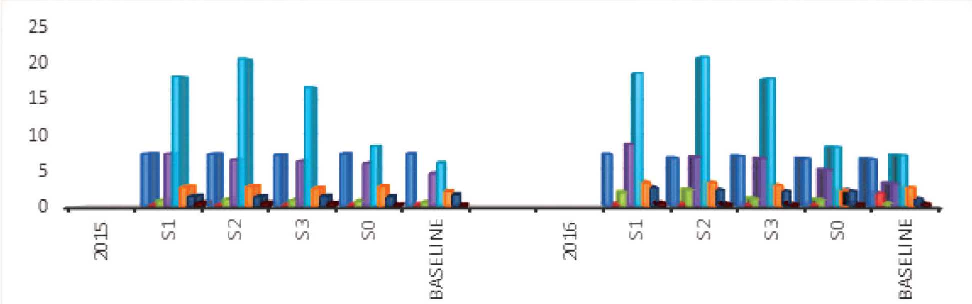
Soil amendments significantly influenced productive ears per plant in both seasons (Table 3). The combined application of biochar @ 3.75 t per ha +compost @ 1.25 kg per ha + NPK @ 60:30:30 kg per ha (S_6) had the highest average number of productive ears per plant in 2015 (0.87) and 2016 (0.99) seasons. Biochar improved mineral retention of the soil by increasing CEC which might improve fertilizer use and increase crop productivity as observed by Mutezo (2013).

Cob yields were significantly influenced by irrigation interval in both seasons (Table 3). As observed for productive ears per plant, irrigation at three days interval consistently recorded higher cob yield (2175 and 2502 kg per ha) in the respective seasons. Similar trend was observed in weed dry weight in both seasons.

In both seasons, weeding significantly influenced cob yields (Table 3). Herbicide application recorded higher cob yield (2015 kg per ha) in 2015 while in 2016, manual hoe weeding had higher yield (2328 kg per ha), which was nevertheless, on par with herbicide application (2303 kg per ha). Weedy check recorded the lowest cob yields in 2015 (788 kg per ha) and 2016 (905 kg per ha) seasons. This could be attributed to competition for environmental resources that were necessary for growth and development as reported by Das (2011).

Soil amendments had significant effect on cob yields in both seasons (Table 3). Plots treated with a combination of biochar @ 3.75 t per ha, compost @ 1.25 kg per ha and NPK @ 60:30:30 kg per ha consistently recorded higher cob yields (2009 and 2368 kg per ha) in the respective seasons. The untreated control plots recorded the lowest yields (902 and 1038 kg per ha) in the respective seasons. The reduced need for inorganic fertilizer as shown in the result signified the potential for savings in both financial and environmental cost of using inorganic fertilizers. The combined use of organic and inorganic amendments resulted in increased yield. Higher mineral composition of the organic amendments (Fig. 1) and their impact on improving soil texture and structure helped greatly in rapid growth and development of the crop. Barrow (2012) opined that it was important to get more from fertilizers, manure or compost because much of the world's food production was in the hands of smallholders with poor access to inputs. This emphasized the need for integrated nutrient management in crop production as reported by Vanlauwe et al. (2010).

The interaction of soil amendments and irrigation interval significantly influenced the number of ears per plant in both seasons. Plots treated with combined application of biochar @ 3.75 t per ha,



	2015	S1	S2	S3	S0	Baseline	2016	S1	S2	S3	S0	Baseline
pH		7.37	7.34	7.23	7.37	7.37		7.31	6.79	7.06	6.74	6.63
EC (dS/m)		0.27	0.27	0.24	0.22	0.27		0.28	0.31	0.25	0.3	1.9
TN (g/kg)		0.89	1.01	0.86	0.74	0.56		1.98	2.33	1.05	0.93	0.53
OC (g/kg)		7.36	6.54	6.34	6.05	4.62		8.7	6.92	6.74	5.13	3.2
AP (mg/kg)		18.16	20.65	16.67	8.47	6.13		18.64	20.89	17.89	8.33	7.17
Ca (cmol/kg)		2.731	2.803	2.551	2.803	2.14		3.39	3.39	3	2.26	2.72
Mg (cmol/kg)		1.449	1.387	1.444	1.371	1.67		2.64	2.36	2.22	2.22	1.15
K (cmol/kg)		0.47	0.47	0.42	0.2	0.21		0.48	0.38	0.37	0.4	0.46

Figure 1. Comparative effects of amendments on soil properties in 2015 ans 2016

compost @ 1.25 kg per ha and NPK @ 60:30:30 kg per ha (S_3) irrigated at three days interval (I_1) produced the highest number of ear per plant in 2015 (2.54) and 2016 (2.93) (Table 4). This was because NPK fertilizer provided readily available mineral elements needed by maize while the mixture and biochar and compost improved water holding capacity of the soil and provide additional mineral element needed by the crop for proper growth. This was supported by the reports of Jan et al. (2014).

The amendments and weeding methods also interacted significantly to affect number of ears per plant in 2015 ($p<0.023$) and 2016 ($p<0.001$) seasons. Manually weeded plots combined with mixed application of biochar @ 3.75 t per ha, compost @ 1.25 kg per ha and NPK @ 60:30:30 kg per ha recorded higher average number of ears per plant in 2015 (2.38) and 2016 (2.73) seasons (Table 5). This meant that where fertilizers were applied, weeding needed to be done to prevent weeds from using the fertilizer and other environmental resources. Weedy check plots irrigated at seven days interval recorded the lowest number of ears per plant in 2015 (0.59) and 2016 (0.68) season. This could be attributed to the severe competition for limited environmental resources between the weed and the crop as reported by Das (2011).

Table 4. Interaction between irrigation intervals and soil amendments on number of ears per plant in 2015 and 2015 season

Soil amendments	Irrigation Intervals (days) 3(I_1)	5(I_2)	7(I_3)
	2015 Season		
S_1	1.49^{e-i}	1.53^{d-i}	1.48^{f-i}
S_2	1.55^{c-i}	1.51^{d-i}	1.20^{gi}
S_3	2.15^{b}	1.64^{d-g}	1.26^{ghi}
S_4	1.82^{c-f}	1.88^{b-e}	1.30^{ghi}
S_5	1.96^{bcd}	1.99^{bc}	1.37^{f-i}
S_6	2.54^{a}	2.02^{bc}	1.57^{c-h}
S_0	1.43^{e-i}	1.49^{d-i}	0.39^{j}
SE	0.219		
	2016 Season		
S_1	1.66^{e-i}	1.76^{d-i}	1.63^{f-i}
S_2	1.78^{c-i}	1.85^{d-i}	1.39^{ghi}
S_3	2.47^{b}	1.89^{d-g}	1.65^{e-i}
S_4	2.09^{c-f}	2.17^{cde}	1.14^{ghi}
S_5	2.19^{bcd}	2.29^{bc}	1.50^{f-i}
S_6	2.93^{a}	2.29^{bc}	1.18^{c-f}
S_0	1.45^{ghi}	1.66^{d-i}	0.45^{j}
SE	0.108		

Means followed by the same letter(s) in row and column are not significantly different at 5% level of probability using HSD tukeys

Table 5. Interaction between weeding methods and soil amendments on number of ears per plant in 2015 and 2015 season

Soil amendments	Weeding Methods		
	W_1	W_2	W_3
	2015 Season		
S_1	1.58^{def}	1.80^{cde}	1.01^{hi}
S_2	1.58^{def}	2.01^{bc}	0.78^{ij}
S_3	2.12^{abc}	2.02^{bc}	1.08^{hi}
S_4	1.83^{cd}	2.02^{bc}	1.15^{hi}
S_5	1.85^{cd}	2.31^{ab}	1.10^{hi}
S_6	2.38^{a}	2.47^{a}	1.29^{fgh}
S_0	1.20^{gh}	1.30^{fgh}	0.59^{j}
SE	0.178		
	2016 Season		
S_1	2.07^{cde}	1.81d^{ef}	1.16^{hi}
S_2	1.75^{efg}	2.31^{bc}	0.91^{ij}
S_3	2.44^{abc}	2.32^{bc}	1.25^{hi}
S_4	2.11^{cde}	2.32^{bc}	1.32^{hi}
S_5	2.63^{cd}	2.66^{ab}	1.26^{hi}
S_6	2.73^{a}	2.84^{a}	1.49^{fgh}
S_0	1.39^{gh}	1.49^{fgh}	0.68^{j}
SE	0.205		

Means followed by the same letter in row and column are not significantly different at 5% level of probability using HSD tukeys

Table 6. Interaction between irrigation intervals and soil amendments on grain yield (kg per hectare) in 2015 and 2015 season

Soil amendments	Irrigation Intervals (days)		
	3(I_1)	5(I_2)	7(I_3)
	2015 Season		
S_1	1282^{e-h}	1178^{ghi}	1062^{ghi}
S_2	1473^{d-g}	1071^{ghi}	1080^{ghi}
S_3	2553^{bc}	1741^{cd}	1319^{e-h}
S_4	1737^{def}	1871^{def}	1152^{def}
S_5	2668^{a}	1649^{def}	1704^{def}
S_6	2788^{a}	1650^{cde}	1689^{efg}
S_0	1128^{ghi}	1017^{hi}	855^{i}
SE	150.3		
	2016 Season		
S_1	1475^{f-i}	1347^{ghi}	1221^{ghi}
S_2	1694^{d-g}	1236^{ghi}	1242^{ghi}
S_3	2934^{bc}	2003^{cd}	1517^{e-h}
S_4	2016^{cd}	2153^{def}	1557^{def}
S_5	3069^{a}	1881^{def}	1295^{def}
S_6	3990^{a}	1897^{cde}	1011^{e-i}
S_0	1296^{ghi}	1169^{hi}	984^{i}
SE	179.9		

Means followed by the same letter (s) in row and column are not significantly different at 5% level of probability using HSD tukeys

Soil amendments and the irrigation interval significantly interacted to affect the grain yield of maize in 2015 ($p<0.007$) and 2016 ($p<0.008$) seasons. Plots treated with combined mixture of biochar @ 3.75 t per ha, compost @ 1.25 kg per ha and NPK @ 60:30:30 kg per ha irrigated at three days interval produced the highest grain yield in 2015 (2788 kg per ha) in and 2016 (3990 kg per ha) seasons (Table 6). The control plots irrigated at seven days interval recorded lowest grain yield (855 and 984 kg per ha) in the respective seasons. Combined applications of biochar @ 3.75 t per ha, compost @ 1.25 kg per ha and NPK @ 60:30:30 kg per ha (S_6) irrigated at three days interval produced higher maize grain yield. The results also indicated that combined incorporation of biochar and compost could appreciably reduce the need for frequent irrigation, especially in the regions where quality water for irrigation was scarce.

The amendments and methods of weeding significantly interacted to affect grain yield of maize in 2015 ($p<0.001$) and 2016 ($p<0.002$) seasons. Herbicide applications with combined applications of biochar @ 3.75 t per ha, compost @ 1.25 kg per ha and NPK @ 60:30:30 kg per ha recorded higher grain yield in 2015 (2688 kg per ha) and 2016 (3100

Table 7. Interaction between weeding methods and soil amendments on grain yield kg per hectare in 2015 and 2016 season

Soil amendments	Weeding Methods		
	W_1	W_2	W_3
	2015 Season		
S_1	903^{cd}	862^{cde}	578^{efg}
S_2	1003^{c}	969^{cde}	438^{g}
S_3	1397^{b}	1683^{b}	527^{fg}
S_4	1691^{b}	1730^{ab}	593^{d-g}
S_5	1792^{b}	1698^{b}	597^{d-g}
S_6	2688^{a}	1628^{b}	546^{d-g}
S_0	771^{c-f}	678^{c-f}	396g
SE	99.6		
	2016 Season		
S_1	1038^{cd}	991^{cde}	456^{g}
S_2	1153^{c}	1124^{c}	646^{g}
S_3	2657^{b}	2676^{b}	807^{fg}
S_4	2210^{b}	2825^{b}	872^{d-g}
S_5	2865^{b}	2902^{b}	957^{d-g}
S_6	3100^{a}	2850^{b}	985^{efg}
S_0	887^{c-f}	956^{c-f}	456^{g}
SE	96.4		

Means followed by the same letter (s) in row and column are not significantly different at 5% level of probability using tukeys kg per ha) seasons (Table 7). The unweeded plots without addition of any amendments had the lowest grain yield in 2015 (594 kg per ha) and 2016 (684 kg per ha). Applying biochar @ 3.75 t per ha, compost @ 1.25 kg per ha and NPK @ 60:30:30 kg per ha was superior to NPK @ 120:60:60 kg per ha alone. This was because apart from containing other essential elements, mixture of biochar and compost improved soil texture and structure which might have helped in reducing moisture and nutrient leaching losses. Steiner et al. (2007) had reported that nutrient uptake, crop growth and yield were significantly increased with application of biochar. The interaction between irrigation interval, weeding method and soil amendment on grain yield of maize was not significant in both seasons.

The short-term effects of adding the amendments (biochar, compost and NPK) at 100 per cent (5 t per ha and 120:60:60 kg per ha) on soil indices of relevance to maize productivity are presented in Fig. 1. Soils amended with compost @ 5 t per ha had the highest N (1.01 and 2.33 g per kg) and available phosphorus (20.65 and 20.89 mg per kg) contents in 2015 and 2016 respectively followed by plots amended with biochar @ 5 t per ha (0.89 and 1.98 g per kg of N; 18.16 and 18.64 mg per kg of available P in 2015 and 2016 seasons respectively). Higher nutrient contents in the soil were recorded in all the treatments compared to the base line values before the experiment. Inorganic fertilizers might encourage higher biomass production which could augment soil organic carbon through rhizhospheric effects and with the application and decomposition of organic amendments, soil N and P levels might rise. These may be rapidly taken up by crop or lost through leaching. The slow release pattern of the organic amendments may however ensure the presence of the nutrients over a prolonged period. This might have accounted for higher grain yield recorded with combined application of biochar and compost, The higher nutrients in compost against biochar may be responsible for the higher nutrient status observed in compost treated plots. The organically amended soils and the control had slightly higher pH than the full fertilizer treated plots which was an obvious advantage if acidity was of concern. The rise in pH, as shown in Fig.1 might be associated with mineral ash content of the various organic materials which resulted in a liming effect as postulated by Liu et al. (2012). Soil applied with biochar recorded higher organic carbon content than that applied with compost and inorganic fertilizer alone during both seasons (Fig. 1). This was an obvious advantage if the target was carbon sequestration. Similar observations were made by Ghosh et al. (2014).

From this study it could be concluded that application of organic amendments significantly affected soil properties and growth of maize. The study demonstrated that combined incorporation of biochar and compost could appreciably reduce the need for frequent irrigation. Irrigation at three days interval with combined applications of biochar @ 3.75 t per ha, compost @ 1.25 kg per ha and NPK @ 60:30:30 kg per ha resulted in the highest maize productivity and could therefore be recommended as alternative maize agronomy in the study area. Similarly application of Primextra @ 1.5 kg a.i. per ha followed by post emergence application of Nicosulfuron (at 6 WAS) @ 0.045 kg a.i. per ha (W_1) with combined applications of biochar @ 3.75 t per ha, compost @ 1.25 kg per ha and NPK @ 60:30:30 kg per ha resulted in higher grain yield and could equally be recommended for weed control in irrigated maize in the study area.

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