YIELD ATTRIBUTES AND YIELD OF UPLAND RICE (ORYZA SATIVAL.) AS AFFECTED BY WEED MANAGEMENT STRATEGIES, SOURCE AND RATE OF BIOCHAR IN NORTHERN GUINEA SAVANNA

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ABSTRACT

Field trials were conducted during 2018 and 2019 wet seasons on the research farm of the Institute for Agricultural Research (IAR), Ahmadu Bello University Samaru, Zaria (11^{o}11'N, 07^{o}38'E 686m above sea level) in the Northern Guinea Savanna ecological zone of Nigeria. The experiment was carried out to evaluate the performance of upland rice (Oryza sativa L.) as affected by weed management strategies, source and rate of biochar. The treatments consisted of three sources of biochar organic biomass (rice husk, groundnut shell and wood shavings), three rates of the biochar (0, 2 and 4 t ha^{-1}) and three different weed management strategies [chemical weed control (Saflufenacil + Dimethenamid-P at 0.5 kg a.i/ha applied pre-emergence), integrated weed control method (Saflufenacil + Dimethenamid-P at 0.5 kg a.i/ha applied pre-emergence + one hand weeding at 9 WAS) and cultural weed control method (Hand weeding at 3, 6 and 9 WAS) which is the farmers' practice]. The three rates of biochar and three different weed management strategies were factorially combined and laid out as the main plot treatment. The sub-plot treatments consisted of the three sources of biochar. All the treatments were laid out in a Split-Plot Design and replicated three times. The results showed that integrated weed management gave the best weed control that enhanced performance of yield attributes such as grain weight per plant, number of grains per panicle and 1000-paddy weight which translated to higher paddy yield of 3.61 t ha^{-1}compared to the chemical weed control. The application of biochar at 2 t ha^{-1} recorded the highest paddy yield of 3.74 t ha^{-1}compared to the control. Incorporation of rice husk biochar enhanced yield parameters such as number of grains per panicle and 1000-paddy weight more than other sources of biochar that translated to paddy yield of 3.18 t ha^{-1}. The results showed that integrated weed control and application of 2 t ha^{-1} rice husk biochar are considered most appropriate for paddy yield of upland rice at Samaru in the Northern Guinea Savanna ecological zone of Nigeria.

Key words: weed management, biochar, upland rice, yield

INTRODUCTION

Rice (Oryza sativa L.) is the most important food crop in the developing world and the staple food of more than half of the world's population (Rajput, 2016). It is among the major sources of employment, income and food security for farming households (FAOSTAT, 2010). Farmers find rice more adaptable than a high input staple like maize when there is declining soil fertility because of the huge array of varieties they can switch over to every few years (Oikeh, et al., 2006). Rice has the potential of growing in virtually all the agro-ecological zones in Nigeria, as diverse as the Sahel Savanna of extreme end of Borno state and the coastal swamps of the extreme end of southwest and south-south (Selbut, 2003). As a special staple food crop, farmers are always willing to grow it all the times no matter the constraints they are facing.

More than 700 million tonnes of paddy rice is produced annually at global level with nearly 640 million tonnes produced in Asia, representing 90% of global production (The United States Department of Agriculture, 2020). The FAO (2020) reported world milled rice production at 508.7 million tonnes in 2020 which is slightly greater than the 507.3 million tonnes of milled rice reported in 2019. Nigeria is reported as the largest paddy rice producer in sub-Saharan Africa with approximately 8 million tonnes out of the Africa average of 14.6 million tonnes of paddy rice annually (USDA, 2020).

Rice production in Nigeria is limited by factors such as lack of good seeds, attack by birds, high cost and unavailability of fertilizer at the time of need, cost of pesticides and weed interference (Akintayo et al., 2011). Of all the constraints limiting the production of rice, weeds, appear to have the most deleterious effect causing between 80 to 100% reduction in potential paddy rice yield (Akobundu, 2011; Imeokparia, 2011; Lavabre, 2011). Weed control is thus important to prevent losses in yield, reduce production cost and preserve good grain quality (Rao et al., 2014). However, the choice and use of appropriate weed control method constitutes yet another constraint to farmers in rice producing regions in Nigeria.

Recently, the use of biochar (a carbon-rich substance) in agriculture is gaining global acceptance because of its variously reported significant benefits which include the potential to reduce current global carbon emissions by about 10 percent thereby mitigating climate change (Woolf, 2008), improved soil fertility leading to reduced need for additional fertilizer, improved water and nutrient retention in sandy soils, reduced nutrient leaching (Atkinson et al., 2010, Downie and Van Zwieten, 2013; Pühringer, 2016), reduced weed seed viability and germinability (Major et al., 2005; Arif et al., 2012) among other benefits. Despite these attributes, utilization of biochar in Nigerian agriculture especially in the savanna region [which is characterized by very low nutrient content (Uyovbisere and Lombin, 1988)] is still low. Upland rice production under the different sources and rates of biochar and weed management systems is yet to be established in the savanna region of Nigeria which this research undertook to determine the best source and optimum rate of biochar and most efficient weed management strategy for upland rice production.

Materials and Methods

Field trials were conducted during 2018 and 2019 wet seasons on the research farm of the Institute for Agricultural Research (IAR), Ahmadu Bello University Samaru, Zaria ($11^{o}11'$N, $07^{o}38'$E 686m above sea level). The experiment was carried out to evaluate the yield performance of upland rice (Oryza sativa L.) as affected by weed management strategies, source and rate of biochar. The treatments consisted of three sources of biochar organic biomass (rice husk, groundnut shell and wood shavings), three rates of the biochar (0, 2 and 4 t ha^{-1}) and three different weed management strategies [chemical weed control (Saflufenacil + Dimethenamid-P at 0.5 kg a.i/ha applied pre-emergence), integrated weed control method (Saflufenacil + Dimethenamid-P at 0.5 kg a.i/ha applied pre-emergence + one hand weeding at 9 WAS) and cultural weed control method (Hand weeding at 3, 6 and 9 WAS) which is the farmers' practice]. The three rates of biochar and three different weed management strategies were factorially combined and laid out as the main plot treatment. The sub-plot treatments consisted of the three sources of biochar. All the treatments were laid out in a Split-Plot Design and replicated three times. The gross plot size was 3m x 3m (9m^2), while net plot size was 3 x 1.5m (4.5m^2).

The biochar was produced locally under low oxygen condition based on the procedure described by Srinivasarao et al. (2013) and analyzed for its chemical properties. The composite of the sampled soil before land preparation and at harvest were analyzed for physical and chemical properties. Land was harrowed twice and demarcated into main-plots and sub-plots. NERICA 8 (FARO 59) variety was used and dressed with Dress Force (Imidacloprid 20%, Metalaxyl-M 20%, Tebuconazole 2% WS) at the rate of 10g/2.5kg of rice seeds. The rice seeds were sown manually by dibbling at an intra and inter-row spacing of 20 x 20cm on flat land. The herbicide Saflufenacil + Dimethenamid-P at 0.5kg a.i. /ha was applied at one day after sowing according to the pre-emergence treatments at a pressure of 2.1kg/cm^2 using discharge volume of 200L/ha. Half recommended rate of fertilizer (i.e. half of 80kgNha^{-1}, 30kgP_2O_5ha^{-1} and 30kgK_2Oha^{-1}) was used for this research applied under 2 split applications at planting and at 5 WAS. Three hand weedings were carried out in the hand-weeded treatment at 21, 42 and 63 DAS and one hand weeding in the integrated weed control treatment at 63 DAS. Matured panicles were harvested manually using sickle at physiological maturity prior to grain shattering. Data were collected on panicle length, number of grains per panicle, 1000-paddy weight and paddy yield per hectare as indicated below:

Grain weight per plant (g)

Panicles from the five tagged plants from each plot were sun-dried, threshed, winnowed and weighed using SB 16001 Mettler Toledo sensitive balance and average weight recorded.

Number of grains per panicle

Grains from the five sampled panicles from each plot were carefully threshed and counted and the mean calculated to determine the number of grains per panicle.

1000-paddy weight (g)

This was determined by randomly counting 1000 rice paddies from each subplot and weighed on SB 16001 Mettler Toledo sensitive balance.

Paddy yield (t ha-^{1})

The paddy yield was obtained from the net plot area of each sub plot. The rice paddies were threshed, winnowed to remove chaff and the clean paddies were weighed using SB 16001 Mettler Toledo sensitive balance and the yield expressed in tonnes per hectare (t ha-^{1}).

Data collected were subjected to statistical analysis of variance (ANOVA) as described by Steel and Torrie (1997) using Statistical Analysis Software package. Treatment means were compared using Duncan Multiple Range Test (DMRT)(Duncan, 1955) at 5% level of probability.

RESULTS

Grain weight per plant (g)

The effect of weed management strategies, rate and source of biochar on grain weight per plant of upland rice at Samaru in 2018 and 2019 wet seasons and the mean is significant (Table 1). Weed management strategy significantly affected grain weight per plant in both years and the mean. Highest grain weight per plant was significantly recorded by integrated weed control and hand weeded treatments more than chemical weed control treatment in both years and the mean.

Application of 2 t ha^{-1} of biochar significantly increased grain weight per plant of upland rice more than all other rates in both years and the mean beyond which there was no further significant increase in grain weight per plant in 2019 and the mean but comparable grain weight per plant at 0 and 4 t ha^{-1} of biochar were observed in 2018 (Table 1).

Source of biochar had no significant effect on grain weight per plant in both years and the mean. The interaction among all the treatments evaluated was not significant in both years and the mean.

Number of grains per panicle

The effect of weed management strategies, rate and source of biochar on number of grains per panicle of upland rice in 2018 and 2019 wet seasons and the mean is significant (Table 1). Significantly highest number of grains per panicle was produced by integrated weed control treatment in 2018 and the mean while integrated weed control and hand weeded methods produced significantly highest number of grains per panicle in 2019. Significantly lowest number of grains per panicle was produced by chemical weed control treatment in both years and the mean.

Application of 2 t ha^{-1} of biochar significantly increased number of grains per panicle of upland rice more than all other rates in both years and the mean beyond which there was no further significant increase in number of grains per panicle but tended to decrease it in 2018.

Rice husk biochar and groundnut shell biochar significantly produced higher number of grains per panicle than wood shavings biochar in both years and the mean. The interaction among all the treatments evaluated was not significant in both years and the mean (Table 1).

1000-paddy weight (g)

The effect of weed management strategies, rate and source of biochar on 1000-paddy weight of upland rice at Samaru in 2018 and 2019 wet seasons and the combined mean is significant (Table 2). Integrated weed control and hand weeded methods which were at par significantly recorded heaviest 1000-paddy weight in both years and the mean while chemical weed control treatment consistently recorded lightest 1000-paddy weight in both years and the mean.

Application of 2 t ha^{-1} rate of biochar significantly increased 1000-paddy weight of upland rice more than all other rates in both years and the mean beyond which 1000-paddy weight comparable to the control was produced in 2018.

Rice husk biochar significantly produced heaviest 1000-paddy weight more than only wood shavings biochar in 2019 and the mean. There was no significant interaction among all the treatments evaluated in both years and the mean.

Paddy yield

Paddy yield per hectare as affected by weed management strategies, rate and source of biochar at Samaru in 2018 and 2019 wet seasons is significant (Table 2). Integrated weed control significantly gave the highest paddy yield per hectare more than other weed management strategies while chemical weed control treatment significantly gave the lowest paddy yield of rice per hectare in both years.

Application of 2 t ha^{-1} of biochar significantly increased paddy yield per hectare more than all other rates in both years. Rice husk biochar significantly produced higher paddy yield per hectare than only wood shavings biochar in 2018.

The interaction between rate of biochar and weed management strategies on paddy yield per hectare (t ha^{-1}) of upland rice was significant at Samaru in 2018 (Table 3). It was observed that integrated weed control treated with 2 t ha^{-1} of biochar significantly produced the highest paddy yield per hectare while chemical weed control without biochar produced the least paddy yield per hectare.

DISCUSSION

Effect of weed management strategies:

It was observed that grain weight per plant, number of grains per panicle, 1000-paddy weight and paddy yield were significantly reduced in the chemical weed control treatment in both years and the mean. This could be due to the vigorous growth of weed species at a later stage of the crop growth cycle recorded in the chemical weed control treatment which led to competition between the weeds and the rice plants for relatively longer period that interfered with the development and performance of yield attributes of the rice plant. Azmi (1990) and Begum et al. (2008) reported that the growth characters and ultimately the yield of rice decreased when weeds were allowed to compete with the rice plants for space, water and nutrients for longer period. Better performance of grain weight per plant, number of grains per panicle, 1000-paddy weight and paddy yield were observed with the integrated weed control strategy probably due to the multiple weed suppression and long season weed control at pre-emergence and hand pulling at 9 WAS. Singh et al. (2002) observed that, maintaining weed free condition till maturity gave significantly higher grain yield due to increased performance of yield attributes and lower density and dry weight of weeds.

Effect of rate of biochar:

Rate of biochar positively influenced yield components and paddy yield of upland rice in both years and the mean. It was observed that application of 2 t ha^{-1} of biochar significantly increased grain weight per plant, number of grains per panicle, 1000-paddy weight and paddy yield. Higher doses of biochar had no further positive effect on the yield components and paddy yield. This indicated that 2 t ha^{-1} of biochar was most appropriate for enhancing yield components of upland rice crop at Samaru. This finding is in agreement with Reichenauer et al. (2009) who found increased grain yield with the application of 2 t rice-husk-biochar ha^{-1}.

Effect of source of biochar:

Rice husk biochar significantly recorded better performance of yield components and paddy yield than other sources of biochar in both years and mean. This could be due to the ability of rice husk biochar to improve the soil properties such as decreased soil bulk density, soil strength, exchangeable Al, and soluble Fe, and increased soil pH, soil organic matter, total P, Mg, Si, CEC, exchangeable K and exchangeable Ca (Masulili and Wani, 2010). The lowest paddy yield recorded with the use of wood shavings biochar in both years could be attributed to the low chemical properties associated with it as revealed by the chemical analysis (Table 4). In accordance, Carvalho et al. (2016) reported that application of wood biochar did not increase yield in rice grown in aerobic soil.

Treatments Interaction:
Interaction between rate of biochar and weed management strategies on paddy yield per hectare was significant in 2018. Integrated weed control in combination with the application of biochar rate at 2 t ha^{-1} gave the highest yield of 4.97 t ha^{-1} in 2018. This indicated the importance of employing the right weed management strategy and appropriate rate of biochar for increased yields of upland rice.

CONCLUSION

The results showed that 2 t ha^{-1} rice husk biochar in combination with integrated weed management is most appropriate for the enhancement of yield components and yield of upland rice at Samaru in Northern Guinea Savanna ecological zone of Nigeria.

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Table 1: Effects of weed management strategy, rate and source of biochar on grain weight per plant and number of grains per panicle of upland rice at Samaru in 2018 and 2019 wet seasons

Treatment	Grain weight per plant (g)			Number of grains per panicle		
	2018	2019	Mean	2018	2019	Mean
Weed management – W						
Chemical weed control	16.2b[2]	14.2b	15.2b	121.0c	109.3b	115.2c
Hand weeding	31.7a	26.9a	29.3a	141.8b	133.2a	137.5b
Integrated weed control	32.9a	24.8a	28.8a	158.6a	143.1a	150.9a
SE±	2.24	1.28	1.76	4.54	4.16	4.35
Biochar rate (t ha^{-1}) – R						
0	22.3b	18.0b	20.1b	122.9c	111.0b	116.9b
2	30.5a	24.3a	27.4a	157.1a	141.7a	149.4a
4	28.1ab	23.6a	25.9a	141.5b	132.9a	137.2a
SE±	2.24	1.28	1.76	4.54	4.16	4.35
Biochar source – S						
Rice husk	29.6	22.6	26.1	156.3a	141.0a	148.6a
G/nut shell	27.1	21.8	24.5	141.5a	132.9a	137.2a
Wood shavings	24.1	21.4	22.8	123.7b	111.8b	117.7b
SE±	3.69	2.02	2.86	5.65	5.55	5.60
Interaction						
R x W	NS[1]	NS	NS	NS	NS	NS
R x S	NS	NS	NS	NS	NS	NS
W x S	NS	NS	NS	NS	NS	NS
R x W x S	NS	NS	NS	NS	NS	NS

1. NS = Not significant.
2. Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability using DMRT.

Chemical weed control (Saflufenacil +Dimethanamid-P); Hand weeding (3, 6, & 9 WAS)
Integrated weed control (Saflufenacil +Dimethanamid-P + Hand weeding at 9 WAS)

Table 2: Effects of weed management strategy, rate and source of biochar on 1000-paddy weight and paddy yield of upland rice at Samaru in 2018 and 2019 wet seasons

Treatment	1000-paddy weight (g)			Paddy yield (t ha^{-1})		
	2018	2019	Mean	2018	2019	Mean
Weed management – W						
Chemical weed control	26.1b[3]	22.4b	24.3b	2.033c	1.856c	1.945c
Hand weeding	30.0a	27.0a	28.5a	2.985b	2.687b	2.836b
Integrated weed control	31.8a	28.0a	29.9a	3.802a	3.419a	3.611a
SE±	1.19	1.18	1.19	0.223	0.244	0.233
Biochar rate (t ha^{-1}) – R						
0	26.6b	23.0b	24.8b	2.078c	1.838b	1.958c
2	31.2a	27.5a	29.4a	3.865a	3.618a	3.741a
4	30.0ab	27.0a	28.5a	2.878b	2.507b	2.692b
SE±	1.19	1.18	1.19	0.223	0.244	0.233
Biochar source – S						

Rice husk	31.9	28.2a	30.0a	3.257a	3.093	3.175
G/nut shell	28.9	25.2ab	27.1ab	2.945ab	2.477	2.711
Wood shavings	27.1	24.1b	25.6b	2.618b	2.392	2.505
SE±	1.24	1.23	1.24	0.229	0.262	0.246
Interaction						
R x W	NS[2]	NS	NS	*[1]	NS	NS
R x S	NS	NS	NS	NS	NS	NS
W x S	NS	NS	NS	NS	NS	NS
R x W x S	NS	NS	NS	NS	NS	NS

1 *= significant at 5% level of probability.
2. NS = Not significant.
3. Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability using DMRT.

Chemical weed control (Saflufenacil +Dimethanamid-P); Hand weeding (3, 6, & 9 WAS)
Integrated weed control (Saflufenacil +Dimethanamid-P + Hand weeding at 9 WAS)

Table 3: Interaction between rate of biochar and weed management on paddy yield per hectare of upland rice at Samaru in 2018

Weed management	Rate of biochar (t ha^{-1})		
	0	2	4
Chemical weed control	1.483g[1]	3.167d	1.450g
Hand weeding	2.071f	3.455c	3.430c
Integrated weed control	2.680e	4.972a	3.730b
SE±		0.070	

[1]Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability using DMRT.

Chemical weed control (Saflufenacil +Dimethanamid-P); Hand weeding (3, 6, & 9 WAS)
Integrated weed control (Saflufenacil +Dimethanamid-P + Hand weeding at 9 WAS)

Table 4: Chemical properties of Biochar at Samaru during 2018 and 2019 wet seasons

Chemical properties	2018			2019		
	RHB	GSB	WSB	RHB	GSB	WSB
pH in water (1:2:5)	10.2	9.86	9.16	10.1	9.58	8.91
pH in 0.01M$CaCl_2$	NA	NA	NA	NA	NA	NA
Organic carbon (g kg^{-1})	171.0	153.0	130.0	163.0	159.6	129.3
Total nitrogen (g kg^{-1})	9.5	8.1	6.5	8.15	7.6	5.91
Phosphorus (mg kg^{-1})	2.85	2.52	1.81	2.15	1.82	1.75
Potassium (cmol kg^{-1})	1.21	1.02	0.95	1.01	1.15	1.26
Sodium (cmol kg^{-1})	0.08	0.06	0.02	1.09	1.05	0.08

Source: Soil Analytical Laboratory, Department of Agronomy, Ahmadu Bello University, Zaria.
RHB – Rice husk biochar, GSB – Groundnut shell biochar, WSB – Wood shavings biochar
NA – Not Applicable