Volume 9, Issue 12, December – 2024 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14613835

Profitability of Upland Rice (Oryza Sativa L.) Production under Different Weed Management Systems, Sources and Rates of Biochar in Kaduna State, Nigeria

[1*]Dr. Yusuf Kuchi TABAT
Department of Agricultural Science Education,
Kaduna State College of Education Gidan Waya, Nigeria

[2]Dr. Jummai Grace TABAT
Department of Home Economics,
Kaduna State College of Education Gidan Waya, Nigeria

Corresponding Author: [1*]Dr. Yusuf Kuchi TABAT

Abstract: - Field trials were carried out concurrently during the rainy season of 2024 on the research farms of the Institute for Agricultural Research, Zaria (11o11'N; 07o38'E 686m above sea level) and Kaduna State College of Education, Gidan Waya (9o34'N, 8o18'E 740m above sea level) located in the northern and southern parts of Kaduna State, which also coincides with the northern and southern Guinea savanna ecological zones of Nigeria, respectively. The experiment was carried out to assess the profitability of upland rice (Oryza sativa L.) production under different weed management systems, source and rate of biochar. The treatments consisted of three different weed management systems [chemical weed control (Saflufenacil + Dimethenamid-P at 0.5 kg a.i/ha applied pre- emergence), integrated weed control (Saflufenacil + Dimethenamid-P at 0.5 kg a.i/ha applied pre- emergence + one hand weeding at 63 DAS) and cultural weed control (Hand weeding at 21, 42 and 63 DAS)], three sources of biochar (groundnut shell, maize cob and wood shavings) and three rates of the biochar (0, 2 and 4 t ha-1). All the treatments were laid out in a Split-Plot Design and replicated three times. The three rates of biochar and three different weed management systems were factorially combined and laid out as the main plot treatment. The sub-plot treatments consisted of the three sources of biochar. The results showed that application of Saflufenacil + Dimethenamid-P at 0.5 kg a.i/ha + one hand weeding at 63 DAS in combination with groundnut shell biochar at 2 t ha-1 gave the highest yield of 3,546 kg/ha and 4,106 kg/ha at Zaria and Gidan Waya, respectively. This also corresponds to the highest return on investment of ₦571,900 with a profit of ₦1.82 per every naira invested at Zaria and ₦702,300 with a profit of ₦2.17 per every naira invested at Gidan Waya. Therefore this treatment is considered most appropriate and profitable for upland rice production in Kaduna State, Nigeria.

I. INTRODUCTION

Rice (Oryza sativa L.) is a staple food crop for more than half of the world's population, which is grown in more than 100 countries with 90% of total global production from Asia (Fukagawa and Ziska, 2019). In large parts of sub-Saharan Africa, rice production and consumption has been increasing more rapidly than any other staple crop (Saito et al., 2023). Nigeria has been 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 is considered an increasingly important crop in Nigeria as it has become part of the everyday diet of many while for others, it has been considered a luxury food for special occasions only (Kamai, et al., 2020).

As a special staple food crop, rice farmers are always willing to grow it all the times no matter the constraints they are facing. 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).

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 management method constitutes yet another constraint to farmers in rice producing regions of Nigeria.

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14613835

The use of biochar (a carbon-rich material produced through pyrolysis of biomass in low-oxygen conditions) in agriculture is gaining global acceptance because of its variously reported significant benefits, which include its ability to sequester carbon (Kuttippurath et al., 2023), improved nutrient retention thereby reducing reliance on chemical fertilizer, improved water and nutrient retention in sandy soils, reduced nutrient leaching (Atkinson et al., 2010, Downie and Van Zwieten, 2013; Pühringer, 2016; Osman et al., 2022), reduced weed seed viability and germinability (Major et al., 2005; Arif et al., 2012) among other benefits. Despite these attributes, utilization of biochar in Kaduna State located in the savanna ecological region of Nigeria is very rare. This region is often characterized by progressively declined soil fertility due to increased pressure on land resources arising from rapid population expansion, which is forcing farmers to adopt continuous cropping (Kamai, et al., 2020). Additionally, there is dearth of information on the profitability of upland rice production under the different weed management systems and sources and rates of biochar in Kaduna State of Nigeria, which this research undertook to determine the most efficient weed management system in combination with the right source and appropriate rate of biochar that would give the highest yield and return on investment to upland rice farmers.

- *Objectives*

The objectives of the study were to determine the most efficient weed management system, the best source of biochar and the optimum rate of biochar for profitable upland rice production.

II. MATERIALS AND METHODS

- *Experimental Sites*

Field trials were carried out concurrently during the rainy season of 2024 on the research farms of the Institute for Agricultural Research (IAR), Zaria (11o11'N; 07o38'E 686m above sea level) and Kaduna State College of Education, Gidan Waya (9o34'N, 8o18'E 740m above sea level) located in the northern and southern parts of Kaduna State, which also coincides with the northern and southern Guinea savanna ecological zones of Nigeria, respectively. The experiment was carried out to assess the profitability of upland rice (Oryza sativa L.) production under different weed management systems, sources and rates of biochar in Nigeria’s Kaduna State.

- *Treatments and Experimental Design*

The treatments consisted of three different weed management systems [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 63 DAS) and cultural weed control method (Hand weeding at 21, 42 and 63 DAS) which is the farmers’ practice], three sources of biochar organic biomass (groundnut shell, maize cob and wood shavings) and three rates of the biochar (0, 2 and 4 t ha-1).The three different weed management systems and three rates of biochar 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 (9m2), while net plot size was 3 x 1.5m (4.5m2).

- *Biochar Production*

The biochar was produced under low-oxygen condition using a local kiln constructed with a metal sheet rolled into a ring-shape with a diameter of 75cm, the bottom, which was properly covered. A metal drum with holes perforated round it was placed at the middle of the constructed ring-shaped metal sheet and surrounded firstly with biochar biomass material. A metal lid was used to cover the biochar biomass. This was to minimize the interference of atmospheric oxygen with the pyrolysis process. Fire was set inside the perforated metal drum using firewood. Heat from the set fire oozing out through the perforated holes of the drum was allowed to gradually burn the biomass material for one hundred and twenty five minutes. Care was taken to ensure that the biomass did not burn into ashes. The fire was put out using water and the carbonized material thus produced spread on the floor to cool for about before use. This production was based on the procedure described by Srinivasarao et al. (2013).

- *Land Preparation, Incorporation of Biochar, Seed Sowing, Herbicide and Fertilizer Application*

The experimental 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/cm2 using discharge volume of 200L/ha. Half recommended rate of fertilizer (i.e. half of 80kgN/ha, 30kgP2O5/ha and 30kgK2O/ha) as given by Kamai, et al. (2020) was used for this research applied under 2 split applications at planting and at 5 WAS.

- *Hand Weeding*

One hand weeding was carried out in the integrated weed control treatment at 63 DAS while three hand weeding were carried out in the hand weeded treatment at 21, 42 and 63 DAS.

- *Harvesting*

Matured panicles were harvested manually according to the treatments using sickle at physiological maturity prior to grain shattering, threshed and winnowed in the air to remove chaff. The paddy grains thus obtained were weighed using SB 16001 Mettler Toledo sensitive balance (Switzerland) and the paddy yield expressed in kilogramme per hectare (kg/ha).

- *Partial Economic Analysis*

Data collected on paddy yield per hectare were subjected to Partial Economic Analysis. This was done to determine the profitability of upland rice production using

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14613835

different weed management systems in combination with various sources and rates of biochar that would give highest yield and return on investment to farmers. The economic analysis was done based on the prevailing market prices of inputs, labour and output of 2024. This was computed based on the procedure described by Olukosi and Erhabor (1988):

GM = TR – TVC

Where:

GM = Gross Margin (₦/ha) TR = Total Revenue (₦/ha)

TVC = Total Variable Cost (sum of labour and material input cost) per hectare

The total revenue was obtained by multiplying paddy yield per hectare (from the different weed management treatments in combination with various sources and rates of biochar) by the price of paddy rice per kilogramme (i.e ₦250/kg).

III. RESULTS

The average cost and return analysis per hectare of growing upland rice using different weed management systems in combination with various sources and rates of biochar at Zaria in 2024 rainy season is presented in Tables 1 and 2. It could be observed that at Zaria, the integrated weed management treatment (W2) and the application of groundnut shell biochar (S1) at 2 t ha-1 (R2) was the most profitable with a gross margin of ₦571,900 and a profit of ₦1.82 per every naira invested. This was closely followed by the integrated weed management treatment (W2) and the application of maize cob biochar (S2) at 2 t ha-1 (R2) which gave a gross margin of ₦505,200 and a profit of ₦1.57 per naira invested (Table 2). However, the chemical weed control treatment (W1) with the application of wood shavings biochar (S3) at 4 t ha-1 brought about a loss of ₦218,600 and ₦0.54 was lost per naira invested (Table 2).

The cost and return analysis per hectare on investment of growing upland rice using different weed management systems in combination with various sources and rates of biochar at Gidan Waya in 2024 rainy season is presented in Tables 3 and 4. Similarly, at Gidan Waya, the integrated weed management treatment (W2) and the application of groundnut shell biochar (S1) at 2 t ha-1 (R2) was the most profitable with ₦702,300 and a profit of ₦2.17 per every naira invested (Table 4). This was closely followed by the integrated weed management treatment (W2) and the application of maize cob biochar (S2) at 2 t ha-1 (R2), which gave a gross margin of ₦519,100 and a profit of ₦1.56 per naira invested. However, the chemical weed control treatment (W1) with the application of wood shavings biochar (S3) at 4 t ha-1 brought about a loss of ₦324,450 and ₦0.79 was lost per naira invested (Table 4).

Table 1 Variable Cost of Weed Management Systems in Combination with Sources and Rates of Biochar Treatments at Zaria in 2024

Treatment	Variable Cost (₦)									Total Variable Cost (₦)
	Seeds & Fertilizer	Land preparation & Seeds sowing	Groundnut shell biochar	Maize cob biochar	Wood shavings biochar	Herbicide	Hand weeding	Pest & disease control	Harvesting, Threshing & Transportation	
W1S1 R1	76,800	80,000	0.00	-	-	12,500	-	10,200	53,400	232,900
W1S2 R1	76,800	80,000	-	0.00	-	12,500	-	10,200	53,400	232,900
W1S3 R1	76,800	80,000	-	-	0.00	12,500	-	10,200	53,400	232,900
W2S1 R1	76,800	80,000	0.00	-	-	12,500	21,500	10,200	53,400	254,400
W2S2 R1	76,800	80,000	-	0.00	-	12,500	21,500	10,200	53,400	254,400
W2S3 R1	76,800	80,000	-	-	0.00	12,500	21,500	10,200	53,400	254,400
W3S1 R1	76,800	80,000	0.00	-	-	-	64,500	10,200	53,400	284,900
W3S2 R1	76,800	80,000	-	0.00	-	-	64,500	10,200	53,400	284,900
W3S3 R1	76,800	80,000	-	-	0.00	-	64,500	10,200	53,400	284,900
W1S1 R2	76,800	80,000	60,200	-	-	12,500	-	10,200	53,400	293,100
W1S2 R2	76,800	80,000	-	67,900	-	12,500	-	10,200	53,400	300,800
W1S3 R2	76,800	80,000	-	-	84,600	12,500	-	10,200	53,400	317,500
W2S1 R2	76,800	80,000	60,200	-	-	12,500	21,500	10,200	53,400	314,600
W2S2 R2	76,800	80,000	-	67,900	-	12,500	21,500	10,200	53,400	322,300
W2S3 R2	76,800	80,000	-	-	84,600	12,500	21,500	10,200	53,400	339,000
W3S1 R2	76,800	80,000	60,200	-	-	-	64,500	10,200	53,400	357,600
W3S2 R2	76,800	80,000	-	67,900	-	-	64,500	10,200	53,400	365,300
W3S3 R2	76,800	80,000	-	-	84,600	-	64,500	10,200	53,400	382,000
W1S1 R3	76,800	80,000	120,400	-	-	12,500	-	10,200	53,400	353,300
W1S2 R3	76,800	80,000	-	135,800	-	12,500	-	10,200	53,400	368,700
W1S3 R3	76,800	80,000	-	-	169,200	12,500	-	10,200	53,400	402,100

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14613835

W2S1 R3	76,800	80,000	120,400	-	-	12,500	21,500	10,200	53,400	388,900
W2S2 R3	76,800	80,000	-	135,800	-	12,500	21,500	10,200	53,400	404,300
W2S3 R3	76,800	80,000	-	-	169,200	12,500	21,500	10,200	53,400	437,700
W3S1 R3	76,800	80,000	120,400	-	-	-	64,500	10,200	53,400	405,230
W3S2 R3	76,800	80,000	-	135,800	-	-	64,500	10,200	53,400	420,630
W3S3 R3	76,800	80,000	-	-	169,200	-	64,500	10,200	53,400	454,030

W1 = Chemical weed control	S1 = Groundnut shell biochar	R1 = 0 t ha-1
W2 = Integrated weed management	S2 = Maize cob biochar	R2 = 2 t ha-1
W3 = Hand weeding	S3 = Wood shavings biochar	R3 = 4 t ha

Table 2 Cost Benefit Analysis of weed Management Systems in Combination with Sources and Rates of Biochar Treatments at Zaria in 2024

Treatment	**Paddy yield (kg/ha)**	**Revenue (₦)**	**Total Variable Cost (₦)**	**Net income (₦)**
W1S1 R1	518	129,500	232,900	-103,400
W1S2 R1	377	94,250	232,900	-138,650
W1S3 R1	361	90,250	232,900	-142,650
W2S1 R1	1388	347,000	254,400	92,600
W2S2 R1	1292	323,000	254,400	68,600
W2S3 R1	2346	586,500	254,400	332,100
W3S1 R1	2298	574,500	284,900	289,600
W3S2 R1	943	235,750	284,900	-49,150
W3S3 R1	643	160,750	284,900	-124,150
W1S1 R2	1790	447,500	293,100	154,400
W1S2 R2	2456	614,000	300,800	313,200
W1S3 R2	1693	423,250	317,500	105,750
W2S1 R2	3546	886,500	314,600	571,900
W2S2 R2	3310	827,500	322,300	505,200
W2S3 R2	2467	616,750	339,000	277,750
W3S1 R2	2396	599,000	357,600	241,400
W3S2 R2	2034	508,500	365,300	143,200
W3S3 R2	2048	512,000	382,000	130,000
W1S1 R3	899	224,750	353,300	-128,550
W1S2 R3	1084	271,000	368,700	-97,700
W1S3 R3	734	183,500	402,100	-218,600
W2S1 R3	2378	594,500	388,900	205,600
W2S2 R3	2738	684,500	404,300	280,200
W2S3 R3	1923	480,750	437,700	43,050
W3S1 R3	2300	575,000	405,230	169,770
W3S2 R3	1806	451,500	420,630	30,870
W3S3 R3	2326	581,500	454,030	127,470

W1 = Chemical weed control	S1 = Groundnut shell biochar	R1 = 0 t ha-1
W2 = Integrated weed management	S2 = Maize cob biochar	R2 = 2 t ha-1
W3 = Hand weeding	S3 = Wood shavings biochar	R3 = 4 t ha

Table 3 Variable Cost of weed Management Systems in Combination with Sources and Rates of Biochar Treatments at Gidan Waya in 2024

Treatment	**Variable Cost (₦)**									**Total Variable Cost (₦)**
	Seeds & Fertilizer	**Land Preparation & Seeds Sowing**	**Groundnut Shell Biochar**	**Maize Cob Biochar**	**Wood Shavings Biochar**	**Herbicide**	**Hand Weeding**	**Pest & Disease Control**	**Harvesting, Threshing & Transportation**	
W1S1 R1	80,000	85,500	0.00	-	-	10,500	-	9,400	56,600	242,000
W1S2 R1	80,000	85,500	-	0.00	-	10,500	-	9,400	56,600	242,000
W1S3 R1	80,000	85,500	-	-	0.00	10,500	-	9,400	56,600	242,000

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14613835

W2S1 R1	80,000	85,500	0.00	-	-	10,500	22,000	9,400	56,600	264,000
W2S2 R1	80,000	85,500	-	0.00	-	10,500	22,000	9,400	56,600	264,000
W2S3 R1	80,000	85,500	-	-	0.00	10,500	22,000	9,400	56,600	264,000
W3S1 R1	80,000	85,500	0.00	-	-	-	66,000	9,400	56,600	308,000
W3S2 R1	80,000	85,500	-	0.00	-	-	66,000	9,400	56,600	308,000
W3S3 R1	80,000	85,500	-	-	0.00	-	66,000	9,400	56,600	308,000
W1S1 R2	80,000	85,500	60,200	-	-	10,500	-	9,400	56,600	302,200
W1S2 R2	80,000	85,500	-	67,400	-	10,500	-	9,400	56,600	309,900
W1S3 R2	80,000	85,500	-	-	84,600	10,500	-	9,400	56,600	326,600
W2S1 R2	80,000	85,500	60,200	-	-	10,500	22,000	9,400	56,600	324,200
W2S2 R2	80,000	85,500	-	67,400	-	10,500	22,000	9,400	56,600	331,900
W2S3 R2	80,000	85,500	-	-	84,600	10,500	22,000	9,400	56,600	348,600
W3S1 R2	80,000	85,500	60,200	-	-	-	66,000	9,400	56,600	368,200
W3S2 R2	80,000	85,500	-	67,400	-	-	66,000	9,400	56,600	375,900
W3S3 R2	80,000	85,500	-	-	84,600	-	66,000	9,400	56,600	392,600
W1S1 R3	80,000	85,500	120,400	-	-	10,500	-	9,400	56,600	362,400
W1S2 R3	80,000	85,500	-	135,800	-	10,500	-	9,400	56,600	377,800
W1S3 R3	80,000	85,500	-	-	169,200	10,500	-	9,400	56,600	411,200
W2S1 R3	80,000	85,500	120,400	-	-	10,500	22,000	9,400	56,600	384,400
W2S2 R3	80,000	85,500	-	135,800	-	10,500	22,000	9,400	56,600	399,800
W2S3 R3	80,000	85,500	-	-	169,200	10,500	22,000	9,400	56,600	433,200
W3S1 R3	80,000	85,500	120,400	-	-	-	66,000	9,400	56,600	428,400
W3S2 R3	80,000	85,500	-	135,800	-	-	66,000	9,400	56,600	443,800
W3S3 R3	80,000	85,500	-	-	169,200	-	66,000	9,400	56,600	477,200

W1 = Chemical weed control	S1 = Groundnut shell biochar	R1 = 0 t ha-1
W2 = Integrated weed management	S2 = Maize cob biochar	R2 = 2 t ha-1
W3 = Hand weeding	S3 = Wood shavings biochar	R3 = 4 t ha

Table 4 Cost Benefit Analysis of weed Management Systems in Combination with Sources and Rates of Biochar Treatments at Gidan Waya in 2024

Treatment	Paddy yield (kg/ha)	Revenue (₦)	Total cost (₦)	Net income (₦)
W1S1 R1	939	234,750	242,000	-7,250
W1S2 R1	668	167,000	242,000	-75,000
W1S3 R1	549	137,250	242,000	-104,750
W2S1 R1	2961	740,250	264,000	476,250
W2S2 R1	1952	488,000	264,000	224,000
W2S3 R1	2349	587,250	264,000	323,250
W3S1 R1	1318	329,500	308,000	21,500
W3S2 R1	1045	261,250	308,000	-46,750
W3S3 R1	1009	252,250	308,000	-55,750
W1S1 R2	2294	573,500	302,200	271,300
W1S2 R2	2258	564,500	309,900	254,600
W1S3 R2	2348	587,000	326,600	260,400
W2S1 R2	4106	1,026,500	324,200	702,300
W2S2 R2	3404	851,000	331,900	519,100
W2S3 R2	3166	791,500	348,600	442,900
W3S1 R2	2670	667,500	368,200	299,300
W3S2 R2	2123	530,750	375,900	154,850
W3S3 R2	2377	594,250	392,600	201,650
W1S1 R3	711	177,750	362,400	-184,650
W1S2 R3	990	247,500	377,800	-130,300
W1S3 R3	347	86,750	411,200	-324,450
W2S1 R3	3255	813,750	384,400	429,350
W2S2 R3	3077	769,250	399,800	369,450

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14613835

W2S3 R3	3063	765,750	433,200	332,550
W3S1 R3	2721	680,250	428,400	251,850
W3S2 R3	1320	330,000	443,800	-113,800
W3S3 R3	1109	277,250	477,200	-199,950

W1 = Chemical weed control	S1 = Groundnut shell biochar	R1 = 0 t ha-1
W2 = Integrated weed management	S2 = Maize cob biochar	R2 = 2 t ha-1
W3 = Hand weeding	S3 = Wood shavings biochar	R3 = 4 t ha

IV. DISCUSSION

Cost benefit analysis was used to determine the best weed management system that would combine with the appropriate source and rate of biochar to achieve maximum benefit or return to farmers at the lowest or minimum cost. The application of Saflufenacil + Dimethenamid-P at 0.5 kg a.i/ha + one hand weeding at 63 DAS in combination with the incorporation of groundnut shell biochar at 2 t ha-1 (W2S1R2) effectively controlled weeds and significantly increased paddy yield per hectare than other weed management methods and sources and rates of biochar at both locations. This, also corresponds to the highest gross margin obtained at both locations. The resultant highest paddy yield per hectare obtained could be due to the adequate early weed suppression achieved with the application of pre- emergence herbicide and the sufficiency of groundnut shell biochar at 2 t ha-1 to improve the soil nutrient status. This is in agreement with Chauhan et al. (2014) who reported the ability of herbicides to arrest weed growth from the beginning of crop growth thereby enhancing the general performance of the crop. Besides, the supplementary hand weeding at 63 DAS greatly reduced population of weeds that later sprouted at the time when efficacy of the pre-emergence herbicide elapsed. Ishaya (2004) reported that for effective suppression of weeds in rice fields, there is the need to follow-up herbicide application with hand weeding especially if there is infestation by rhizomatous, bulbiferous, corms and Striga weeds on the field. The ability of biochar to reduce weed seed viability and germinability thereby enhancing growth and yield performances of crop was also reported by Major et al. (2005) and Arif et al. (2012). Reichenauer et al. (2009) reported increase in rice paddy yield with the application of 2 t ha-1 biochar more than at 4 t ha-1. Also, Ogawa and Okimori (2010) observed that the addition of low amounts of biochar had notable effects on various plant species whereas higher doses appeared to limit plant growth.

On the other hand, the lowest profit margin came from the treatment to which Saflufenacil + Dimethenamid-P at 0.5 kg a.i/ha was applied together with the incorporation of wood shavings biochar at 4 t ha-1 at both locations. The low paddy yield obtained could be attributed to the high weed interference that occurred at later stage of the crop's growth since there was no supplementary weed control. This had resulted in competition for resources such as soil moisture, sunlight, nutrients and space between the rice plants and weeds, which reduced the expected paddy yield. Walia (2006) reported that the greatest crop loss was caused by weeds as a result of their competition with crop plants for growth factors such as nutrients, soil moisture, light and space. This suggests that the paddy yield produced might not be able to upset the cost of production. Therefore, for profitable upland rice production in Kaduna State, it will be beneficial and cost effective if rice farmers adopt the application of Saflufenacil + Dimethanamid-P at 0.5 kg a.i/ha + hand weeding at 63 DAS and the incorporation of groundnut shell biochar at 2 t ha-1.

V. CONCLUSION

From the result obtained, it can be concluded that application of Saflufenacil + Dimethenamid-P at 0.5 kg a.i/ha + one hand weeding at 63 DAS in combination with groundnut shell biochar at 2 t ha-1 which gave the highest paddy yield and return on investment of 3,546 kg/ ha and ₦571,900, respectively at Zaria and the highest paddy yield and return on investment of 4,106 kg/ha and ₦702,300, respectively at Gidan Waya is considered most appropriate and profitable for upland rice production in Kaduna State, Nigeria.

ACKNOWLEDGMENTS

The authors hereby express their genuine acknowledgments to the Tertiary Education Trust Fund (TETFUND), Abuja and the Kaduna State College of Education, Gidan Waya for granting them the sponsorship to carry out this study.

REFERENCES

[1]. Akintayo, O.I., May, R., Awoyemi, T.T. and Adeoti, A.I. (2011). Determinants of Yield Gap in Lowland Rice Production in North-Central Nigeria. African Journal Online, 11 (1): 1- 10.
[2]. Akobundu, I. O. (2011). Weed Control in Direct-seeded Lowland Rice under Poor water Control Conditions. Weed Research, 21:273-278.
[3]. Arif, M., Ali, K., Munsif, F., Ahmad, A., Ahmad,W. and Naveed, K. (2012). Effect of biochar, FYM and nitrogen on weeds and maize phenology. Pakistan Journal of Weed Science Research, 18(4): 475-484.
[4]. Atkinson, C. J., Fitzgerald, J. D. and Hipps, N. A. (2010). Potential mechanisms for achieving agricultural benefits from biochar application to temperate soils: a review. Plant and Soil, 337(1- 2):1-18.
[5]. Chauhan, B.S., Kumar, V. and Mahajan, G. (2014). Research needs for improving weedmanagement in rice. Indian Journal of Weed Science, 46: 1-13.

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14613835

[6]. Downie, A. and Van Zwieten, L. (2013). Biochar: A Coproduct to Bioenergy from Slow-Pyrolysis Technology. In: Advanced Biofuels and Bioproducts. Springer New York, pp. 97-117.

[7]. Fukagawa, N.K. and Ziska, L.H. (2019). Rice: Importance for Global Nutrition. J Nutr Sci Vitaminol (Tokyo). 2019;65(Supplement):S2-S3. doi:10.3177/jnsv.65.S2.PMID: 31619630.

[8]. Imeokparia, P. O. (2011). Control of Cut grass (Leersia hexandra) in Direct seeded Lowland Rice at Badeggi. Agronomy Seminar, Ahmadu Bello University, Zaria.

[9]. Ishaya, D. B. (2004). Evaluation of chemical weed management practices on rainfed upland Rice/Sorghum Mixture. Unpublished Ph.D. Thesis, Department of Agronomy, Ahmadu Bello University, Zaria. Pp156 – 162.

[10]. Kamai, N., L.O. Omoigui., A,Y. Kamara., F. Ekeleme (2020). Guide to Rice Production in Northern Nigeria. International Institute of Tropical Agriculture, Ibadan, Nigeria. 27pp

[11]. Kuttippurath, J., Abbhishek, K., Chander, G., Dixit, S., Singh, A., Das, D., Dey, S. (2023). Biochar-based nutrient management as a futuristic scalable strategy for C-sequestration in semiarid tropics. Agronomy Journal 115(5):2311-2324.

[12]. Lavabre, E. M. (2011). The Tropical Agriculturist: Weed Control, pp.86.

[13]. Major, J., Steiner, C., Ditommaso, A., Falcao, N.P.S.and Lehmann, J. (2005). Weed composition and cover after three years of soil fertility management in the central Brazilian Amazon: compost,fertilizer, manure and charcoal applications. Weed Biology Management, 5: 69– 76.

[14]. Ogawa, M., and Okimori, Y. (2010). Pioneering works in biochar research, Japan. Soil Research, 48(7): 489-500.

[15]. Oikeh, S.O., Nwilene F.E., Agunbiade T.A., Oladimeji O., Ajayi O., Semon M., Tsunematsu,H. and Samejina, H. (2006). Growing upland rice: a production hand book- Africa Rice Center (WARDA) Cotonou, Benin, pp 2-3.

[16]. Olukosi, J.O. and Erhabor, P.O. (1988). Introduction to Farm Management Economics. Ajitab Publishers, Zaria pp35 - 36 and 71 - 80.

[17]. Osman, A.L., Fawzy, S., Farghali, M., EL-Azazy,M., Elgarahy, A.M., Fahim, R.A., Rooney, D.W. (2022). Biochar for Agronomy, animal farming, anaerobic digestion, composting, water treatment, soil remediation, construction, energy storage, and carbon sequestration: a review. Environ. Chem. Lett 20(4):2385-2485.

[18]. Pühringer, H. (2016). Effects of different biochar application rates on soil fertility and soil water retention in on-farm experiments on smallholder farms in Kenya. Master's Thesis in Environmental Science, Department of Soil and Environment, Faculty of Natural Resources and Agricultural Sciences, Swedish University of Agricultural Sciences. Uppsala 2016.

[19]. Rao, A.N., Wani, S.P. and Ladha, J. K. (2014).Weed, management research in India - an analysis of the past and outlook for future pp. 1 -26. In: Souvenir (1989-2014). DWR Publication No. 18. Directorate of Weed Research, Jabalpur, India.

[20]. Reichenauer, T.G, Panamulla, S., Subasinghe, S., & Wimmer, B. (2009). Soil amendments and cultivar selection can improve rice yield in salt- influenced (tsunami-affected) paddy fields in Sri Lanka. Environmental Geochemical Health, 31: 573–579.

[21]. Saito, K., Senthilkumar, K., Doussou-Yovo, E.R., Ali, Johnson, J.M., Mujawamariya, G. and Rodenburg, J. (2023). Status quo and challenges of rice production in sub-Saharan Africa. Plant Production Science, 26:3, 320-333.

[22]. Selbut R. L. (2003). Review and Description of Rice Production Systems in Nigeria: Multi- agency Partnerships in West African Agriculture. Eco-systems Development and Organization. Pp.9.

[23]. Srinivasarao, Ch., Gopinath, K. A., Venkatesh, G., Dubey, A. K., Harsha Wakudkar Purakayastha, T. J., Pathak, H., Pramod Jha, Lakaria, B. L., Rajkhowa, D. J., Sandip Mandal, Jeyaraman, S., Venkateswarlu, B. and Sikka, A.

[24]. K. (2013). Use of biochar for soil health management and greenhouse gas mitigation in India: Potential and constraints, Central Research Institute for Dryland Agriculture, Hyderabad, Andhra Pradesh. Pp 6 -17.

[25]. United States Department of Agriculture (2020). World Rice Production, Consumption and Stocks Foreign Agricultural Services, PSD Reports.Pg1. https://apps.fas.usda.gov/psdonline/app/index.h tml a Walia, U.S. (2006). Weed management. New Delhi: Kalyani publishers Woolf, D. (2008). Biochar as soil amendment: A review of the environmental implications. Nature, 1-10.