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Research Article

Influence of Sowing Techniques and Timing of Herbicide Application on Weed Infestation and Yield of Rice in Southern Guinea Savannah of Nigeria

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Abstract

Field trias were conducted at the research field of National Cereals Research Institutes Badeggi experimental field, Niger state located at (latitude $9^{o}04^{1}$ 02.05''N and longitude $0.6^{o}01^{1}$ 3.31''E) and Bacita located at (latitude 9^{o1} 16'N and longitude $5^{o}59$'E) both in the Southern Guinea Savannah Agro Ecological Zone of Nigeria during the wet season of 2021 and 2022. To determine the best combination of sowing techniques and time of herbicide application for optimizing rice yield while minimizing weed infestation and crop injury in the Southern Guinea Savannah of Nigeria. The experiment consisted of five sowing methods (broadcasting dry, broadcasting wet, dibbling wet, dibbling dry, and transplanting) and two herbicide application timings (2 and 3 weeks after sowing) were tested in a factorial experiment. Data were collected on weed count before herbicide application, weed count at harvest and grain yield per hectare. The results indicated that the transplanting technique of sowing significantly improved rice productivity in the study area at both seasons, less weed infestation at harvest was recorded with transplanted methods compared to other panting techniques, herbicide application at early growth stage of 2WAS promote healthy crop growth and minimize weed competition with rice crop.

Keywords: *Sowing, Herbicide, Broadcasting, Dibbling, Transplanting, crop, injury*

Introduction

Rice (*Oryza sativa* L.) a member of the Poaceae family, is a staple food for over 60% of the global population, serving as a primary source of nutrition (ICAR, 2006). In Nigeria, it plays a vital role in agriculture and daily food consumption, providing approximately 20% of the world's dietary energy. Rice is an excellent source of essential nutrients, such as calories, protein, fat, and carbohydrates, contributing two-thirds of the average Nigerian's caloric intake and half of their protein intake. To meet the demands of the growing global population, rice production must increase from 520 million tonnes to 880 million

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tonnes by 2025, as forecasted by CGIAR (2023). This can be achieved through the adoption of advanced farming techniques and high-yielding rice varieties. However, challenges such as water scarcity, rising fertilizer costs, and labor shortages necessitate the implementation of effective agronomic practices to ensure sustainable rice production.

Africa, despite accounting for only 2.6% of global rice cultivation area and 4.6% of the population, produces an average of 14.6 million tonnes of rice annually on 7.3 million hectares, as reported by AfricaRice (2022). West Africa dominates the continent's rice production, covering 56.5% of the land area, approximately 3.7 million hectares. In Nigeria, rice has become a staple food across all social classes, with demand surpassing other staples. The country's annual rice consumption is 5.4 million metric tons, worth over $9.2 billion. However, domestic production only reaches 2.3 million metric tons, resulting in a significant import deficit of 3.1 million metric tons. Nigerian farmers face substantial challenges in boosting productivity, including optimizing establishment methods, effective weed control, and fertilizer application, all of which significantly impact rice yields, as noted by Arouna *et al.* (2017).

Rice production faces numerous challenges, with weed growth being the most significant obstacle. Weeds can reduce rice yields by 75-100% by competing for resources such as water, nutrients, and light. (Akobundu, 2011; Imeokparia, 2011; Lavabre, 2011). No-tillage rice is more vulnerable to weed competition than transplanted rice, especially when using dwarf varieties and fertilizers. Poor weed control can lead to 40% production losses. Early weed control is crucial in direct sowing, where rice seeds and weeds germinate simultaneously. Farmers have various weed control methods, including chemical treatments, traditional practices, and manual weeding (Street and Lanham, 2016). Effective weed management requires precise timing and method selection, with herbicide efficacy being critical. Researchers have identified effective herbicides for different growth stages, including pre-plant, burn-down, pre-emergence, and post-emergence treatments. (Mahajan and Chauhan, 2022; Allen, 2012). Specific herbicides like thiobencarb, pendimethalin, and ethoxysulfuron have proven effective in controlling weeds in direct-seeded rice systems. (Kumar *et al.*, 2018; Mahajan and Chauhan, 2022).

In Nigeria, rice farmers employ various planting techniques, including broadcasting, dibbling on ridges, and random or row transplanting (Fukagawa and Ziska, 2019). While row transplanting is touted as a means to increase rice yields in lowland areas, it demands substantial water and labor resources. To address these challenges, direct seeding is now being advocated as a more efficient and labor-saving approach that conserves water (Kamai *et al.,* 2020).

In Nigeria, manual weeding is the traditional method, but it's no longer viable due to labor shortages and increasing costs. Moreover, distinguishing between rice seedlings and weeds, particularly grasses, is difficult during the early growth stage, making manual weeding ineffective. (Kamai *et al*., 2020). Therefore, herbicides are considered the most effective solution for weed control in direct-seeded rice (DSR) (Sanjoy *et al.,* 2019). Pre-emergence herbicide application is crucial for efficient weed management in DSR. However, selecting the right herbicide is essential for cost-effective weed suppression. Environmental factors, such as soil moisture, can impact herbicide efficacy and crop safety by affecting absorption, translocation, or metabolism. To boost rice production and meet the growing population's demands, it's essential to optimize rice planting methods, nitrogen rates, and herbicide application timing based on prevailing conditions. (Sanjoy *et al.,* 2019).

Despite the importance of optimizing rice production, there is a lack of knowledge on the best planting method and time of herbicide application for achieving high yields in this agro-ecological zone. This study aims to fill this knowledge gap by investigating the effects of different planting methods and time of herbicide application on rice productivity, with the goal of identifying the most effective practices for improving yields.

Materials and Methods

The experiment was conducted at the research fields of National Cereals Research Institute headquarters, Badeggi, Niger state. National Cereals Research Institutes Badeggi experimental field is located at (latitude 9°04' 02.05''N and longitude 0.6°01' 3.31''E), in the southern Guinea Savannah Agro Ecological Zone of Nigeria. The experiment was carried out during the wet season of 2021 and 2022 in the two locations.

The trials were carried out in two years during the raining season. The experiment consisted of factorial combinations of five planting methods (dry-seeding broadcasting, wet-seeding broadcasting, dry-seeding dibbling, wet-seeding dibbling and row transplanting methods) and two time of herbicide application (2 and 3 weeks after sowing). The (10) treatments combinations with three replications were laid down in a factorial experiment laid out in a randomized complete block design. The gross plot size was $9m^2$ (3m x 3m) and net plot size was $4m^2$ (2m x 2m).

The experimental field was prepared according to standard procedures, involving ploughing, harrowing, leveling, and manual bounding. In both locations, nursery beds were created for sowing seeds and raising seedlings, which were later transplanted to the field. Both direct seeding and broadcasting were done using both dry and pre-germinated seeds. A nursery was established for the seedlings, which were later transplanted at 14 days after establishment at a rate of 2 seedlings per hole. Both transplanting and direct seeding were done with a spacing of 20 x 20 cm. The FARO 44 rice seed variety was used, with the following seeding rates: 25 kg/ha for transplanting, 50 kg/ha for direct seeding, and 60 kg/ha for broadcasting.

A basal application of NPK 15:15:15 fertilizer was applied on the day of sowing or transplanting, prior to sowing or transplanting. The first topdressing with Urea was applied 3-4 weeks after sowing or transplanting, followed by a second topdressing with Urea 6-8 weeks after sowing or transplanting, according to the specified fertilizer rates for each treatment.

Throughout the experimental period, there were no occurrences of pest or disease outbreaks. As a result, no pesticides were applied during the experiment. The rice field was harvested when 80-85% of the panicles had turned yellow or brown, which occurred around 14-16 weeks after sowing (WAS). Harvesting was done using a rice sickle. Threshing was done manually using a drum on a tarpaulin. The seeds were then separated from the chaff through winnowing, a process that uses air to blow away the lighter chaff, leaving the heavier seeds behind.

In each plot, five hills were randomly selected and tagged for data collection, and the following parameters were recorded: Weed count at 2 weeks before herbicides application Weed density using quadrant (25 cm x25 cm) at 3, 6, 9 and 12 WAS.
Total grain at harvest was determined by weighing the grains from each net plot with a Mettler scale Model 1210 and the value obtained was converted to per hectare basis.
Data analysis was performed using GENSTAT software (2008 edition). Analysis of Variance (ANOVA) was conducted using the General Linear Model Procedure. Least Significant Difference (LSD) was used to compare means at a 5% level of probability ($P \leq 0.05$).

Results and Discussion

According to Table 1, the initial physical and chemical analysis of the soils at the experimental sites during the 2021 and 2022 cropping seasons showed that the soil texture was predominantly sandy clay, with a slightly acidic to neutral pH range of 6.9 to 7.1 across both years. The soils had a moderate organic carbon content of 2.5-2.8%, relatively low total nitrogen levels, moderate available phosphorus, and low exchangeable cation levels, consistent with the soil characteristics described by Peter *et al.* (2006).

Table 2 shows the effects of sowing methods on weed count before herbicide application in 2021 and 2022 at Bacita and Badeggi. In 2021 and 2022, wet dibbling method of sowing produced significantly higher weed count before herbicide application similar to the dry dibbling method of sowing in 2022 compared to other methods of sowing. However, in 2021 and 2022 at Badeggi, broadcasting wet and transplanting methods of sowing produced significantly similar higher weed count before herbicide application compared to other methods of sowing respectively.

Herbicide application timing had significant influence on weed count before application in both years and locations (Table 2). Herbicide application at 3WAS significantly produced higher number of weeds before application with the exception at Badeggi in 2022, where 2WAS recorded significantly higher number of weeds before herbicide application. Overall, the reduced weed count observed with herbicide application at 2WAS compared to 3WAS underscores the importance of early weed control in enhancing weed management efficiency. This finding is consistent with Shamim *et al.* (2008), who noted improved weed control effectiveness with early herbicide application.

Weed count at harvest was significantly influenced by methods of sowing at Bacita and Badeggi in 2021 and 2022. Table 3 shows that at both locations, broadcasting wet method of sowing significantly increased number of weeds at harvest in 2021 compared to other sowing methods. However, in 2022, the reverse is the case where broadcasting dry method of sowing recorded highest number of weeds at both locations.

Herbicide application at 3WAS produced significantly higher number of weeds at harvest compared to other herbicide time of application. The weed count in transplanted rice plots at 12 weeks after sowing (12WAS) was significantly lower compared to other plots with other sowing methods, reflecting effective weed suppression. This finding supports previous studies by Shamim *et al*. (2008), who observed fewer weeds in transplanted rice plots compared to directly seeded rice.

The transplanting and dibbling methods showed significantly higher grain yield per hectare. This outcome was attributed to wider spacing which reduce competition between the crop in terms of air, water and adequate nutrient promoting rapid growth, efficient metabolic processes, and enhanced carbohydrate mobilization, which collectively facilitated robust cell division and elongation.
Table 6 shows the interaction effects between sowing methods and herbicide application time on rice grain yield per hectare in 2021 and 2022 at Bacita and Badeggi. In 2021, the combination of broadcasting dry sowing method and 3WAS herbicide application resulted in significantly higher grain yields at Bacita, while transplanting method of sowing with 3WAS significantly increased grain yields at Badeggi compared to other method of sowing and time of herbicide application. In 2022, transplanting method of sowing with 3WAS resulted in significantly higher grain yield per hectare at Bacita, and transplanting sowing method with 2 and 3WAS significantly produced similar grain yield per hectare at Badeggi (Table 6).

The significant interactions between sowing methods and time of herbicide application on yield and yield components showed that transplanting method of sowing with herbicides application at 2WAS produced highest value for grain yield and yield attributes.

Conclusion

The weed count in transplanted rice plots at 12 weeks after sowing (12WAS) was significantly lower compared to other sowing methods, reflecting effective weed suppression. Overall, the reduced weed count observed with herbicide application at 2WAS compared to 3WAS underscores the importance of early weed control in enhancing weed management efficiency. Transplanting method of sowing produced significantly higher grain than other methods of sowing. Transplanting method of sowing combined with herbicide application resulted in proper rice growth, development and yield.
Based on the study's findings, the following recommendations are made:

Transplanting technique is the recommended planting method for improved rice productivity in the study area. Applying herbicide at early growth stage of 2 weeks after sowing (2 WAS) is recommended for proper weed control and effectiveness of the herbicides. Combine of precision transplanting method with optimal herbicide application timing of 2WAS is recommended for optimal weed management and crop yield.

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Table 1: Physical and Chemical Properties of Soil in the Experimental Site for the both wet seasons

Properties	Badeggi	Bacita	Combined
PH	7.3	6.9	7.1
O.C.%	1.82	1.80	1.81
O.M.%	3.12	3.09	3.11
N%	0.35	0.28	0.32
Avail P (ppm)	12.35	8.43	10.39
K	0.34	0.30	0.32
Na	0.21	0.19	0.20
Ca	3.56	3.21	3.39
Mg	2.86	2.15	2.51
EA	0.50	0.67	0.59
TEB	6.97	5.85	6.41
CEC	7.47	6.52	7.00
B.S.%	93%	89%	91%
Particle size analysis			
Sand %	78.6	74.6	76.6
Silt %	5.4	5.4	5.4
Clay %	16	20	18
Texture	Sandy loam	Sandy loam	Sandy loam

Table 2 Effect of Sowing Methods, Timing of Herbicide Application and NPK Fertilizer Rates on Weed Count Before Herbicides Application in 2021 and 2022 at Bacita and Badeggi.

	Weed Count Before Herbicides Application			
	2021		2022	
Treatments	Bacita	Badeggi	Bacita	Badeggi
Sowing Methods (S)				
Broadcast dry	11.58e	12.37b	15.50b	15.66b
Broadcast wet	12.51b	12.73a	15.16c	15.33bc
Dibbling dry	12.32c	12.37b	15.83a	14.83c
Dibbling wet	14.21a	11.39d	15.83a	12.69d
Transplanting	12.08d	11.84c	11.33e	16.16a
SE±	0.03	0.03	0.00	0.01
Timing of Herbicide Application (H)				
2 WAS	12.05b	11.26b	14.86b	16.87a
3 WAS	13.63a	12.42a	15.60a	15.97b
SE±	0.02	0.02	0.00	0.00
Interactions				
S x H	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. [1]Weeks after sowing; [2]not significant difference at 5% level of probability

Table 3: Effect of Sowing Methods, Timing of Herbicide Application and NPK Fertilizer Rates on Weed Count at Harvest in 2021 and 2022 at Bacita and Badeggi

Weed Count at Harvest				
	2021		2022	
Treatments	Bacita	Badeggi	Bacita	Badeggi
Sowing Methods (S)				
Broadcast dry	114.81b	114.81b	140.66a	148.50a
Broadcast wet	120.84a	120.84a	138.66b	148.00b
Dibbling dry	110.18c	110.18c	112.16d	114.83c
Dibbling wet	96.77d	96.77d	132.50c	103.00d
Transplanting	56.74e	56.74e	67.66e	58.00e
SE±	0.04	0.04	0.01	0.00
Timing of Herbicide Application (H)				
2 WAS	96.48b	92.46b	110.13b	115.20b
3 WAS	103.26a	101.16a	114.73a	116.73a
SE±	0.02	0.03	0.02	0.01
Interactions				
S x H	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. [1]Weeks after sowing; [2]not significant difference 5% level of probability

Table 5: Effects of Sowing Methods and Time of Herbicides Application on Grain Yield per Hectare in 2021 and 2022 at Bacita and Badeggi

Paddy Yield (Kg/ha-^{1})				
Treatments	2021		2022	
	Bacita	Badeggi	Bacita	Badeggi
Sowing Methods (S)				
Broadcast dry	3185.31c	2977.54c	2945.69d	3833.33d
Broadcast wet	3270.69d	2638.47d	2988.61c	3930.56cd
Dibbling dry	3194.58c	3152.50c	4507.78b	4333.33c
Dibbling wet	3623.61ab	3495.69b	4813.89a	5277.78b
Transplanting	3940.56a	4882.50a	4912.78a	6073.19a
SE±	90.76	110.10	122.82	83.08
Timing of Herbicide Application (H)				
2 WAS	3487.83	3576.91a	3990.50	4883.33a

3 WAS	3554.07	3201.78b	3787.00	4495.94b
SE±	57.40	69.64	77.67	52.545
Interactions				
S x H	**	**	**	**

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. [1]Weeks after sowing; [2]not significant difference at 5% level of probability

Table 6: Interaction Effect of Sowing Methods (S) x Time of Herbicide (H) Application on Rice Grain Yield per Hectare at Badeggi and Bacita in 2021 and 2022

	Time of Herbicide Application							
Sowing Methods	Bacita 2021		Badeggi 2021		Bacita 2022		Badeggi 2022	
	2WAS	3WAS	2WAS	3WAS	2WAS	3WAS	2WAS	3WAS
Broadcast dry	2321.67g	1714.58h	2506.19h	3048.89f	2908.33i	2983.06h	3444.44h	4222.22e
Broadcast wet	3262.92e	3013.75f	3144.44e	2132.50i	3355.00g	2622.22j	3722.22g	4138.89f
dibbling dry	3088.75f	3508.33d	3221.39d	3083.61f	3443.33f	3972.22e	4333.33d	4333.33d
Dibbling wet	3410.08cd	3533.75c	4328.61c	2662.78g	5083.33ab	4544.44d	4888.89c	5666.67b
Transplanting	4411.67a	3610.83b	4683.89b	5081.11a	5141.67a	4683.89c	6090.83a	6055.56a
SE (±)	48.3		64.6		42.1		65.4	

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. [1]Weeks after sowing; [2]not significant difference at 5% level of probability