Journal of Agriculture and Ecology Research International

20(3): 1-14, 2019; Article no.JAERI.52972
ISSN: 2394-1073

Growth Response of Selected Rice (*Oryza sativa* L.) Varieties to Integrated Weed Management in Sudan Savanna of Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author AAA carried out the experiment analyzed the data and prepared the first draft. Authors AM and AIY performed statistical analysis and supervised the activity. Author HYS provided guidance and edited the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAERI/2019/v20i330106
Editor(s):
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Complete Peer review History: http://www.sdiarticle4.com/review-history/52972

Short Research Article

Received 08 October 2019
Accepted 14 December 2019
Published 21 December 2019

ABSTRACT

Rice is a weak competitor against weeds and the majority of African farmers have few options and resources available for effective weed control. Weed control is one of the most important and suggestive practices for potential rice production. Field trials were carried out during 2017/2018 dry season at the Teaching and Research Fadama farm of the Kebbi State University of Science and Technology located at Jega (Latitude 12º21ˈN; Longitude 4º36ˈE) and that of Usmanu Danfodiyo University Sokoto located at Kwalkwalawa (Latitude 13º01ˈN, Longitude 5º09ˈE) to study the

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effects of integrated weed management (IWM) and variety on weed occurrence and the growth of rice. Both locations lie within Sudan Savanna ecological zone of Nigeria. The treatments consisted of six (6) weed management options (Solarization/Orizo-plus (3 WAT)/Hoe-weeding (6 WAT), Round-up/Orizo-plus (3 WAT)/Hoe-weeding (6WAT), Solarization/Hoe-weeding (3 WAT)/Hoe-weeding (6 WAT), Round-up/Hoe-weeding (3 WAT)/Hoe-weeding (6 WAT), Weedy-check and Weed-free) and three (3) rice varieties (Jamila, Faro 44 and Faro 57). The factorial combinations of the treatments were laid out in a randomized complete block design (RCBD) with the split-plot arrangement and were replicated three times. Weed management options formed the main plots while rice varieties were assigned to the sub-plots. The result of the study indicated that combination of solarization, orizo-plus and hoe-weeding achieved an effective weed control (33.56 g weed dry matter per m^2) close to the weekly hoe-weeding (16.13 g weed dry matter per m^2). Faro 57 variety was noted with the potential to increase rice growth under good weed management practices. From the results, it could be concluded that for increased rice growth, Faro 57 under the combination of solarization, orizo-plus and hoe-weeding IWM option should be adopted.

Keywords: Growth; integrated weed management; rice varieties; Sudan savanna.

1. INTRODUCTION

Rice (*Oryza spp.*) is grown worldwide including Asian, North and South American, European Union, Middle Eastern and African countries. *Oryza sativa* and *O. glaberrima* are the two cultivated species of rice among the 25 recognized species [1]. *Oryza sativa* is more widely grown than *O. glaberrima*. Globally, rice ranks third after wheat and maize in terms of production [2]. It supplies one or more of the three macronutrients (carbohydrates, proteins and fats) and also micronutrients and minerals vital for survival and health [2]. Rice supplies 2,808 calories/person/day which contributes a major percentage of the total calorie needed and it is a source of income to more than 100 million households around the world [3]. Rice stands out as the major food crop for about half of human race.

Weeds are unwanted plants, which succeed in the struggle for existence in competition with crops [4]. Weeds compete with crops for the limited environmental resources such as light, water, nutrients and even space. Weeds also serve as alternate hosts to pests and pathogens which usually affect crops in the field and during storage [5]. Adigun [6] reported that the percentage losses due to unchecked weed growth on different cereals are appreciable in crops like wheat, maize, sorghum, rice, rye, oats etc. In rice cultivation system, the longer the presence of weeds in rice cropping paddy, the greater the reduction of grain yield [7,8,9]. In West Africa, it has been shown that farmers can increase their rice yields by 15–23% through applying relatively basic measures to improve weed control, such as bunding of fields to retain floodwater and timely interventions such as herbicide applications and hand weeding. Integrated weed management will be more compatible with farmers' resources than single-component technology that may require a high level of external inputs [10]. There is, therefore, need to carry out a study on the compatibility of different types of weed management strategies and their suitability to rice production.

2. MATERIALS AND METHODS

2.1 Experimental Site

The trials were carried out during 2017/2018 dry season at the Teaching and Research Fadama farm of the Kebbi State University of Science and Technology located at Jega (Latitude 12º21ˈN; Longitude 4º36ˈE) and that of Usmanu Danfodiyo University Sokoto located at Kwalkwalawa (Latitude 13º01ˈN, Longitude 5º09ˈE). Both locations lie within the Sudan Savanna ecological zone of Nigeria.

2.2 Experimental Design and Treatments

The treatments consisted of six (6) weed management options (Solarization/Orizo-plus(3WAT)/Hoe-weeding(6WAT), Round-up/Orizo-plus(3WAT)/Hoe-weeding(6WAT), Solarization/Hoe-weeding(3WAT)/Hoe-weeding(6WAT), Round-up/Hoe-weeding(3WAT)/Hoe-weeding(6WAT), Weedy-check and Weed-free) and three (3) rice varieties (Jamila, Faro 44 and Faro 57). The factorial combinations of the treatments were laid out in a randomized complete block design (RCBD) with split-plot arrangement and were replicated three times. Weed management options formed the

main plots while rice varieties were assigned to the sub-plots. The dimensions of the individual plots were 4x3 m (12 m^2). Main-plots were spaced at 0.7 m apart; blocks at 1.5 m apart and water channels were well constructed for effective irrigation. The inter and intra-row spacing was 20×20 cm with two seedlings per stand and 20 rows of 15 stands in each plot. The net plot area (2 m^2) contained the ten (10) middle rows for growth and yield assessment; while the boarder rows were used for destructive sampling.

2.3 Cultural Practices

The fields were cleared, ploughed, harrowed and leveled. Three nursery beds, one each for Faro 44, Faro 57 and Jamila variety of 5x2 m (10 m^2) were made. The beds were fertilized with NPK 15:15:15 at 50 gm^{-2}. Rice seeds were sown by drilling at an inter-row spacing of 30 cm. Irrigation was made in every two days interval to supply adequate water. Rice seedlings were transplanted four (4) weeks after sowing when the seedlings were at 4-5 leaf stage at a spacing of 20x20 cm. Transplanting at Jega location took place on 13th March, 2018 while Sokoto location was on 22nd March, 2018. The plant population was 250,000 plants per hectare. Gap filling was done after one (1) week of transplanting to maintain the plant population in the experimental field. Basal application of NPK 15:15:15 fertilizer was done at the rate of 45 kg ha^{-1} of N, K_2O and P_2O_5 before transplanting. Urea was applied in split form at 4 weeks after transplanting (WAT) (46 kg ha^{-1}N) and 8WAT (44 kg ha^{-1}N). Surface irrigation method was used to fill up the basin, every three (3) days interval from transplanting and was later increased to two (2) days interval when evapotranspiration increased. The weed control was done as per treatment.

2.4 Data Collection

Four (4) plants were randomly selected and tagged from each net plot. Plant height, tiller number and leaf area index were assessed from the tagged plants at 6, 8 and 10 weeks after transplanting. The total number of weeds from 1 m^2 quadrat (weed density) of each plot was collected from the net plot at 3, 6 and 9WAT. Collected weeds were air-dried and later oven-dried at 75ºC to a constant weight. The electronic weighing balance was used to measure the dry weight and expressed as g per m^2.

3. RESULTS AND DISCUSSION

3.1 Response to Integrated Weed Management

Weed control has been identified by Parthipan, et al. [11] as one of the most important and

Table 1. Weed species identified and their level of occurrence in rice fields at Jega and Sokoto during 2017/2018 dry season

Weed species	Location	
	Jega	Sokoto
	Level of occurrence	
Grasses		
Chloris pilosa Schumach	***	***
Digitaria horizontalis Wild.	**	**
Echinochloa colona (Linn.) Link	*****	*****
Oryza bathii A. Chev.	**	**
Paspalum scrobiculatum Linn.	**	**
Sorghum arundinaceum (Desv.) Stapf.	***	-
Broad leaves		
Amaranthus viridis Linn.	-	*
Indigofera spicata Forskk	**	*
Mimosa pigra Linn.	*	*
Vernonia cinerea (Cass.) Less.	**	*
Vernonia galamensis (Cass.) Less.	*	*
Sedges		
Cyperus rotundus Linn.	*	**
Kyllinga pumila Michx.	*	**
Pycreus lanceolatus (Poir.) C. B. Cl.	**	**

** = Very low occurrence, ** = Low occurrence, *** = Moderate occurrence, **** = High occurrence, *****===Very high occurrence, - = Absent*

suggestive practices for potential rice production [12,13]. A total of 14 weed species were identified (Table 1), which include: Grasses, broad-leaved and sedges. Among the identified weed species, the grass *Echinochloa colona* (Linn.) Link was found to have the highest occurrence at both locations. Its dominance could be attributed to the fact that it is a common weed of rice and grows in a wide range of soil moisture conditions, from swampy soils to dry land [14].

Higher weed dry matter was recorded among the weedy-check treatments while lower weed dry matter was observed among weed-free treatment and combination of solarization, orizo-plus and hoe-weeding (Table 2). This indicated that weed thrives when left uncontrolled in rice and they respond to measures aimed at controlling them. Combination of solarization, orizo-plus and hoe-weeding treatment was only inferior to the weed-free treatment in terms of weed control effectiveness. At 3WAT, a combination of solarization, hoe-weeding and hoe-weeding treatment was statistically the same with a combination of solarization, orizo-plus and hoe-weeding treatment. This implies that solarization effectively controlled weeds at the early stage of rice plant. At 9WAT, combination of round-up, orizo-plus and hoe-weeding treatment were statistically at par with a combination of solarization, orizo-plus and hoe-weeding treatment. The result therefore suggests that combination of orizo-plus and hoe-weeding at the later stage of rice plant controls weed better than resorting to only hoe-weeding twice. This agrees with the findings of Singh, et al. [15], where combination of herbicides and manual weed control gave a significant weed control effect in the rice field.

Growth parameters such as plant height (Table 5), number of tillers (Table 7) and leaf area index (Table 9) were significantly affected by the integrated weed management treatments. Significant increase in plant height was observed with combination of solarization, orizo-plus and hoe-weeding which could be attributed to the facts that its combination options effectively lowered weed population thereby reducing competition by weeds and ensured the availability of growth resources. Also, the production of shorter plants observed in weedy-check treatment at both locations could be attributed to the high population of weeds in competition for growth resources. These results agree with Na–Allah et al. [16], who reported that weed competition for growth resources in plants usually retards growth due to very high interspecific competition.

More tillers per plant as well as leaf area index was produced by the weed-free treatment and that of a combination of round-up, hoe-weeding and hoe-weeding. This can be linked to the effective weed control which suppresses weed growth thereby reducing competition for growth factors between the crop and weeds. Similarly, the fewer tillers, as well as leaf area index produced by the weedy-check treatment, could be attributed to competition between weeds and crop plants for moisture and nutrients such that plant could not produce more tillers and leaves. Adigun [17] reported that intense weed competition in the weedy-check reduced leaf area index of the crop.

3.2 Varietal Response

Varietal difference in weed dry matter was observed at both locations during 3WAT while at 6WAT, it was observed only at Sokoto location (Table 2). The varietal effect consistently revealed that both Faro 44 and Faro 57 had the highest weed dry matter while Jamila had the lowest weed dry matter. The results imply that varietal weed suppression occurs in rice at the early stage. Also, Jamila, which is a local variety compete better with weeds than the other two improved varieties during the early growth stage of rice. These findings agree with the statement of Jonne and David [10] that choice of rice cultivar by farmers is often influenced by the cultivar's ability to suppress or compete with weeds.

The growth parameters such as plant height (Table 5), number of tillers (Table 7) and leaf area index (Table 9) were significantly affected by variety. Jamila produced taller rice plants, followed by Faro 57 while Faro 44 had shorter plants throughout the sampling periods at both locations and the combined. The taller plants produced by Jamila can be linked to its genetic ability to attain such height. This result conforms to the findings of Nwokwu, et al. [18], where Jamila produced taller plants among the varieties cultivated.

A number of tillers showed a similarly significant effect on rice variety. Both Faro 44 and Faro 57 produced more tillers while Jamila recorded the least at both locations and the combined mean. The more tillers recorded by Faro 44 and Faro 57 can be attributed to their improved genetics,

Table 2. Weed dry matter of rice as influenced by integrated weed management and variety at Jega, Sokoto locations and the combined during 2017/2018 dry season

Treatment	Weed dry matter (g)								
	Jega			Sokoto			Combined		
	3 WAT	6 WAT	9 WAT	3 WAT	6 WAT	9 WAT	3 WAT	6 WAT	9 WAT
Integrated weed management									
Solarization/orizo-plus/hoe-weeding	22.37c	24.24d	21.38c	19.99d	20.31c	19.10c	21.18c	22.28d	20.24c
Round-up/orizo-plus/hoe weeding	99.91b	43.09c	19.38c	85.20b	24.70c	16.27c	92.56b	33.89c	17.82c
Solarization/hoe-weeding/hoe weeding	28.57c	66.62b	38.61b	23.24d	36.28b	32.60b	25.19c	51.45b	35.61b
Round-up/hoe-weeding/hoe weeding	92.39b	65.23b	42.60b	76.79c	41.67b	37.54b	84.59b	53.45b	40.07b
Weedy-check	207.68a	247.74a	272.70a	168.68a	224.65a	244.91a	188.18a	236.20a	258.81a
Weed-free	7.40d	6.49e	6.27d	6.74e	6.30d	6.30d	7.07d	6.39e	6.28d
SE±	**3.193**	**2.004**	**2.193**	**1.237**	**2.718**	**2.564**	**2.953**	**3.248**	**2.315**
Variety									
Jamila	69.05b	77.62	69.01	57.36b	53.46b	56.75	63.20b	65.54	62.88
Faro 44	77.10a	72.27	65.24	65.38a	61.17a	59.91	71.24a	68.22	62.58
Faro 57	83.01a	73.83	66.22	67.59a	62.32a	61.70	75.30a	68.08	63.96
SE±	**2.258**	**1.417**	**1.550**	**0.875**	**1.922**	**1.868**	**2.088**	**2.297**	**1.627**
Interaction									
Integrated weed management x Variety	*	NS	*	*	NS	NS	*	NS	NS

*Within a treatment group, means in a column followed by the same letter(s) are not significantly different using DMRT at 5% level of probability. NS = not significant, * = significant, WAT = Weeks after transplanting*

Table 3. Interaction of integrated weed management and variety of weed dry matter at 3 WAT for Jega, Sokoto locations and the combined during 2017/2018 dry season

Jega			
		Variety	
Integrated weed management	**Jamila**	**Faro 44**	**Faro 57**
Solarization/orizo-plus/hoe-weeding	20.77h	24.13h	22.20h
Round-up/orizo-plus/hoe weeding	93.70e	100.63d	105.40d
Solarization/hoe-weeding/hoe weeding	20.77h	31.67g	33.27g
Round-up/hoe-weeding/hoe weeding	86.93f	94.63e	95.60de
Weedy-check	185.63c	202.97b	234.43a
Weed-free	6.50i	8.57i	7.13i
SE±		**5.523**	
Sokoto			
Solarization/orizo-plus/hoe-weeding	19.43i	20.57i	19.97i
Round-up/orizo-plus/hoe weeding	84.57d	81.87e	89.17d
Solarization/hoe-weeding/hoe weeding	19.33i	24.07h	26.33g
Round-up/hoe-weeding/hoe weeding	68.17f	81.73e	80.47e
Weedy-check	146.13c	177.07b	182.83a
Weed-free	6.50j	6.97j	6.77j
SE±		**2.143**	
Combined			
Solarization/orizo-plus/hoe-weeding	20.10h	22.35h	21.08h
Round-up/orizo-plus/hoe weeding	89.13e	91.25e	97.28d
Solarization/hoe-weeding/hoe weeding	20.05h	27.87g	29.80g
Round-up/hoe-weeding/hoe weeding	77.55f	88.18e	88.03e
Weedy-check	165.88c	190.02b	208.63a
Weed-free	6.50i	7.77i	6.95i
SE±		**5.116**	

Means followed by the same letter(s) are not significantly different using DMRT at 5% level of probability. WAT = Weeks after transplanting

giving them the capacity to produce number of tillers in the same environmental condition with the unimproved Jamila variety. This is in conformity with the report of USAID [19], where both Faro 44 and Faro 57 were grouped among improved high yielding rice varieties released for utilization in Nigeria.

The influence of variety on leaf area index was significant and followed a similar trend at both locations throughout the sampling periods. Faro 57 had higher leaf area index followed by Faro 44 while Jamila had the least. The higher leaf area index produced by Faro 57 and then Faro 44 can be attributed to their genetic improvement, enabling them to perform better than the local Jamila variety. This agrees with USAID [19], where both Faro 44 and Faro 57 were grouped among improved high yielding rice varieties.

3.3 Interaction

A significant interaction of IWM and variety on weed dry matter was observed during 3WAT at both locations and the combine (Table 3) while at 9WAT (Table 4), it was only observed at Jega location. The more significant interaction effect of IWM and variety on weed dry matter observed at Jega could be ascribed to the more weed infestation it recorded during the growing season. Low level of weed occurrence was observed among the three varieties when treated with weed free. Observation during 3WAT at Jega revealed that the three varieties treated with a combination of solarization, orizo-plus and hoe-weeding and Jamila variety treated with a combination of solarization, hoe-weeding and hoe-weeding were statistically at par in weed dry matter with the varieties treated with weed-free. This could be as a result of solarization effectively controlling weed at the early stage of rice plant. Observation at Jega during 9WAT revealed that when Faro 57 variety was treated with the combination of polarization, orizo-plus and hoe-weeding and combination of round-up, orizo-plus and hoe-weeding, it was statistically at par in weed dry matter with the varieties treated with weed-free. This could be as a result of Faro 57 effectively maximizing the selective nature of orizo-plus applied during the 6WAT to suppress weed growth. This findings therefore suggest that Faro 57 could be adopted by farmers as [10] revealed that choice of rice cultivar by farmers is often influenced by the cultivar's ability to suppress or compete with weeds.

The interdependency of IWM and variety in giving a synergetic effect among the growth parameters was confirmed in terms of plant height (Table 6), number of tillers (Table 8) and leaf area index (Table 10). Interaction of IWM and variety on plant height was only observed at Jega location during 10WAT. Jamila variety expressed its maximum height when treated with weed-free and a combination of solarization, orizo-plus and hoe-weeding. This complementary effect of IWM and variety on plant height can be linked to Jamila variety being a tall rice variety among the varieties used and the conducive environment provided by the weed management. This agrees with the findings of Nwokwu, et al. [18], where Jamila produced taller plants among the varieties cultivated and Adekpe [20] observed that crops are known to perform better under good weed management.

Table 4. Interaction of integrated weed management and variety of weed dry matter at 9 WAT for Jega location during 2017/2018 dry season

	Jega		
Integrated weed management	**Variety**		
	Jamila	**Faro 44**	**Faro 57**
Solarization/orizo-plus/hoe-weeding	26.27de	20.57e	17.30ef
Round-up/orizo-plus/hoe weeding	22.30e	18.87e	16.97ef
Solarization/hoe-weeding/hoe weeding	51.60c	30.67de	33.57d
Round-up/hoe-weeding/hoe weeding	39.57d	43.40cd	44.83cd
Weedy-check	267.80b	271.10ab	279.20a
Weed-free	6.50f	6.87f	5.43f
SE±		**3.798**	

Means followed by the same letter(s) are not significantly different using DMRT at 5% level of probability. WAT = Weeks after transplanting

Table 5. Plant height of rice as influenced by integrated weed management and variety at Jega, Sokoto locations and the combined during 2017/2018 dry season

Treatment	Plant height (cm)								
	Jega			Sokoto			Combined		
	6 WAT	8 WAT	10 WAT	6 WAT	8 WAT	10 WAT	6 WAT	8 WAT	10 WAT
Integrated weed management									
Solarization/orizo-plus/hoe-weeding	56.89a	67.86b	75.84a	50.90b	62.11bc	70.89b	53.89ab	64.98b	73.37b
Round-up/orizo-plus/hoe weeding	55.67ab	65.74c	74.04b	44.84c	79.79cd	67.06cd	50.26cd	62.77bc	70.55c
Solarization/hoe-weeding/hoe weeding	51.77c	63.98d	71.50c	46.43c	59.20d	68.87bc	49.10d	61.59c	70.18c
Round-up/hoe-weeding/hoe weeding	52.42c	65.69c	73.63b	51.18b	63.71b	69.96b	51.84bc	64.70b	71.79bc
Weedy-check	46.25d	55.04e	67.54d	46.49c	56.44e	65.93d	46.37e	55.74d	66.74d
Weed-free	55.42b	69.54a	76.24a	55.94a	70.89a	78.88a	55.68a	70.22a	77.56a
SE±	**0.483**	**0.512**	**0.517**	**0.757**	**0.936**	**0.696**	**0.845**	**0.804**	**0.690**
Variety									
Jamila	57.83a	71.92a	80.03a	54.76a	68.62a	76.26a	56.30a	70.27a	78.15a
Faro 44	49.63c	60.21c	67.83c	45.33c	56.81c	65.28c	47.48c	58.51c	66.56c
Faro 57	51.79b	61.80b	71.54b	47.80b	60.65b	69.24b	49.79b	61.23b	70.39b
SE±	**0.342**	**0.362**	**0.367**	**0.535**	**0.662**	**0.492**	**0.597**	**0.568**	**0.488**
Interaction									
Integrated weed management x Variety	NS	NS	*	NS	NS	NS	NS	NS	NS

*Within a treatment group, means in a column followed by the same letter(s) are not significantly different using DMRT at 5% level of probability. NS = not significant, * = significant, WAT = Weeks after transplanting*

Table 6. Interaction of integrated weed management and variety on plant height at 10 WAT for Jega location during 2017/2018 dry season

Integrated weed management	Jega		
	Variety		
	Jamila	Faro 44	Faro 57
Solarization/orizo-plus/hoe-weeding	83.93a	71.33de	72.27d
Round-up/orizo-plus/hoe weeding	80.63b	69.37e	72.13d
Solarization/hoe-weeding/hoe weeding	78.40b	66.27f	69.83de
Round-up/hoe-weeding/hoe weeding	80.83b	68.73ef	71.33de
Weedy-check	72.23d	62.07g	68.33ef
Weed-free	84.17a	69.23e	75.33c
SE±		**0.896**	

Means followed by the same letter(s) are not significantly different using DMRT at 5% level of probability. WAT = Weeks after transplanting

Table 7. Number of tillers of rice as influenced by integrated weed management and variety at Jega, Sokoto locations and the combined during 2017/2018 dry season

Treatment	Number of tillers								
	Jega			Sokoto			Combined		
	6 WAT	8 WAT	10 WAT	6 WAT	8 WAT	10 WAT	6 WAT	8 WAT	10 WAT
Integrated weed management									
Solarization/orizo-plus/hoe-weeding	10.89c	16.89c	21.44b	9.67d	14.33e	18.56d	10.28d	15.61c	20.00d
Round-up/orizo-plus/hoe weeding	10.44c	14.44d	18.94c	13.78bc	16.78d	22.33c	12.11c	15.61c	20.39d
Solarization/hoe-weeding/hoe weeding	14.00b	16.67c	22.67b	13.11c	18.00c	24.33b	13.56b	17.33b	23.50c
Round-up/hoe-weeding/hoe weeding	17.89a	21.89a	25.89a	14.67b	19.67b	25.44b	16.28a	20.78a	25.67b
Weedy-check	9.22d	12.11e	14.44d	8.89d	10.89f	13.89e	9.06e	11.50d	14.17e
Weed-free	17.56a	19.78b	27.22a	16.00a	24.22a	29.78a	16.78a	22.00a	28.50a
SE±	**0.452**	**0.669**	**0.502**	**0.394**	**0.408**	**0.470**	**0.412**	**0.528**	**0.477**
Variety									
Jamila	8.33b	12.06b	16.89b	7.28b	10.94b	16.22b	7.81b	11.50b	16.56b
Faro 44	16.17a	19.39a	24.00a	15.22a	20.33a	25.22a	15.70a	19.86a	24.61a
Faro 57	15.50a	19.44a	24.17a	15.56a	20.67a	25.72a	15.33a	20.06a	24.94a
SE±	**0.319**	**0.473**	**0.355**	**0.279**	**0.288**	**0.333**	**0.292**	**0.374**	**0.337**
Interaction									
Integrated weed management x Variety	NS	NS	*	NS	NS	*	NS	NS	*

*Within a treatment group, means in a column followed by the same letter(s) are not significantly different using DMRT at 5% level of probability. NS = not significant, * = significant, WAT = Weeks after transplanting*

Table 8. Interaction of integrated weed management and variety on a number of tillers at 10 WAT for Jega, Sokoto locations and the combined during 2017/2018 dry season

Integrated weed management	Variety		
	Jamila	**Faro 44**	**Faro 57**
Jega			
Solarization/orizo-plus/hoe-weeding	18.67h	23.33e	22.33f
Round-up/orizo-plus/hoe weeding	13.67k	20.00g	21.67f
Solarization/hoe-weeding/hoe weeding	15.33j	25.33d	27.33c
Round-up/hoe-weeding/hoe weeding	20.00g	28.00c	29.67b
Weedy-check	11.33l	15.33j	16.67i
Weed-free	22.33f	32.00a	27.33c
SE±		**0.869**	
Sokoto			
Solarization/orizo-plus/hoe-weeding	16.33hi	20.00g	19.33g
Round-up/orizo-plus/hoe weeding	18.00h	22.67f	26.33e
Solarization/hoe-weeding/hoe weeding	13.67j	28.67d	30.67c
Round-up/hoe-weeding/hoe weeding	17.00h	29.00d	30.33c
Weedy-check	10.00k	16.00i	15.67i
Weed-free	22.33f	35.00a	32.00b
SE±		**0.815**	
Combined			
Solarization/orizo-plus/hoe-weeding	17.50i	21.67f	20.83g
Round-up/orizo-plus/hoe weeding	15.83j	21.33fg	24.00e
Solarization/hoe-weeding/hoe weeding	14.50k	27.00d	29.00bc
Round-up/hoe-weeding/hoe weeding	18.50h	28.50c	30.00b
Weedy-check	10.67l	15.67j	16.17j
Weed-free	22.33f	33.50a	29.67b
SE±		**0.826**	

Means followed by the same letter(s) are not significantly different using DMRT at 5% level of probability. WAT = Weeks after transplanting

Table 9. Leaf area index of rice as influenced by integrated weed management and variety at Jega, Sokoto locations and the combined during 2017/2018 dry season

Treatment	Leaf area index								
	Jega			Sokoto			Combined		
	6 WAT	8 WAT	10 WAT	6 WAT	8 WAT	10 WAT	6 WAT	8 WAT	10 WAT
Integrated weed management									
Solarization/orizo-plus/hoe-weeding	2.06d	3.87d	4.97d	1.58e	3.35e	4.49e	1.82d	3.61d	4.37d
Round-up/orizo-plus/hoe weeding	1.71e	3.18e	4.29e	1.86d	3.82d	5.35d	1.79d	3.50d	4.82d
Solarization/hoe-weeding/hoe weeding	2.22c	4.08c	6.24c	2.22c	4.83c	6.95c	2.22c	4.46c	6.59c
Round-up/hoe-weeding/hoe weeding	2.91b	5.22b	6.91b	2.77b	5.78b	7.40b	2.84b	5.40b	7.16b
Weedy-check	1.56f	2.82f	4.08e	1.20f	2.31f	2.89f	1.38e	2.56e	3.48e
Weed-free	3.05a	5.81a	7.89a	3.31a	7.73a	9.44a	3.18a	6.77a	8.67a
SE±	**0.032**	**0.049**	**0.074**	**0.038**	**0.066**	**0.082**	**0.055**	**0.155**	**0.152**
Variety									
Jamila	1.50b	3.34c	4.53c	1.33c	3.12c	4.79c	1.92b	3.18c	4.66c
Faro 44	2.60a	4.45b	6.10b	2.50b	5.19b	6.59b	2.55a	4.82b	6.35b
Faro 57	2.65a	4.80a	6.56a	2.64a	5.49a	6.88a	2.65a	5.15a	6.72a
SE±	**0.022**	**0.034**	**0.032**	**0.027**	**0.047**	**0.058**	**0.039**	**0.110**	**0.108**
Interaction									
Integrated weed management x Variety	NS	NS	*	NS	NS	*	NS	NS	*

*Within a treatment group, means in a column followed by the same letter(s) are not significantly different using DMRT at 5% level of probability.NS = not significant, * = significant, WAT = Weeks after transplanting*

Table 10. Interaction of integrated weed management and variety of leaf area index at 10 WAT for Jega, Sokoto locations and the combined during 2017/2018 dry season

Integrated weed management	Variety		
	Jamila	**Faro 44**	**Faro 57**
Jega			
Solarization/orizo-plus/hoe-weeding	4.53g	5.21f	5.18f
Round-up/orizo-plus/hoe weeding	3.43i	4.04h	5.39ef
Solarization/hoe-weeding/hoe weeding	3.96h	6.88d	7.87b
Round-up/hoe-weeding/hoe weeding	5.68e	7.21cd	7.84b
Weedy-check	2.29j	4.62g	5.32ef
Weed-free	7.28c	8.66a	7.74b
SE±		**0.128**	
Sokoto			
Solarization/orizo-plus/hoe-weeding	4.07h	4.63g	4.76g
Round-up/orizo-plus/hoe weeding	4.98f	5.32f	5.74e
Solarization/hoe-weeding/hoe weeding	4.07h	7.91d	8.88c
Round-up/hoe-weeding/hoe weeding	5.87e	7.65d	8.69c
Weedy-check	1.90j	3.27i	3.49i
Weed-free	7.82d	10.76a	9.74b
SE±		**0.143**	
Combined			
Solarization/orizo-plus/hoe-weeding	4.30d	4.92cd	4.96cd
Round-up/orizo-plus/hoe weeding	4.20d	4.68d	5.57cd
Solarization/hoe-weeding/hoe weeding	4.01d	7.39b	8.38b
Round-up/hoe-weeding/hoe weeding	5.78c	7.43b	8.26b
Weedy-check	2.10e	3.94d	4.40d
Weed-free	7.54b	9.71a	8.73ab
SE±		**0.264**	

Means followed by the same letter(s) are not significantly different using DMRT at 5% level of probability. WAT = Weeks after transplanting

When Faro 44 was treated with weed-free at both locations during 10 WAT, more tillers per plant as well as leaf area index was recorded. This results could be because Faro 44 is a fast-growing improved variety, thereby quickly expressing its growth ability before reaching the reproductive stage and the effective weed control in the weed-free treatment that eliminates weed competition with the rice plant. However, Faro 57 treated with a combination of round-up, hoe-weeding and hoe-weeding was only inferior to Faro 44 treated with weed-free in terms of tillers per plant at 10 WAT. The superior performance of Faro 44 and then Faro 57 in terms of tillers per plant as well as leaf area index under weed-free and combination of round-up, hoe-weeding and hoe-weeding IWM could be attributed to their genetic improvement and the effective weed control treatment. This agrees with USAID [19], where both Faro 44 and Faro 57 were grouped among improved high yielding rice varieties and Adekpe [20] observed that crops are known to perform better under good weed management.

4. CONCLUSION

From the results obtained, Faro 57 variety has increase rice growth under good weed management practices. Solarization as a weed control measure is effective around the first three weeks after its application. The combination of orizo-plus and hoe-weeding would give a better weed control than resorting to only hoe-weeding twice. Combination of solarization, orizo-plus and hoe-weeding can achieve a similar weed control with the weekly hoe-weeding.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/52972