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Full Length Research Paper

Weed competitiveness and yield of inter-and intra-specific upland rice (*Oryza sativa* L.) under different weed control practices at Badeggi, Niger State, Nigeria

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A field study was conducted at the National Cereals Research Institute, Badeggi (9°04 N, 6°7 E), Niger ia in 2007 and 2008 to compare the weed competitiveness and yield of inter- and intra-specific upland rice (*Oryza sativa* L.) under different weed control practices. The trial was laid out in a split-plot and arranged in a randomized block design with the two varieties of rice NERICA 1 (inter-specific) and FARO 46 (intra-specific) assigned to the main plot, while seven weed control treatments (hoe weeding once at 25 or 45 days after sowing (DAS), twice at 25 and 45 DAS, thrice at 25, 45 and 65 DAS, application of 3,3-dichloropropionanilide+2,4-dichlorophenoxy acetic acid (orizo plus® by Candel) at 3.5 kg a.i ha^{-1} at 25 DAS, hoe weeding at 25 DAS followed by orizo plus® at 3.5 kg a.i ha^{-1} at 45 DAS and a weedy check (control)) constituted the sub-plots. The treatments were replicated three times. The results indicated that the rice variety NERICA 1 had better weed suppression ability and higher grain yield (3.1 t ha^{-1}) than FARO 46 (2.4 t ha^{-1}). Weed control was better when hoe weeding was done thrice and twice and hoe weeding at 25 DAS followed by application of orizo plus® at 45 DAS, in that order, than other treatments. It is concluded that inter-specific NERICA 1 was more weed suppressive and produced greater grain yield than its counterpart.

Key words: Weed competitiveness, inter- and intra-specific upland rice, weed control practices, grain yield.

INTRODUCTION

Upland rice is cultivated on rain fed well drained non-irrigated field which accounts for 35% of the land area for rice production in Nigeria (Singh et al., 1997). Weeds constitute a big constraint to upland rice production, being the greatest problem to increasing yields and quality of rice in Nigeria. Weeds were the most widely reported biological constraint to yield in a survey of upland rice producing countries covering 80% of the total production area, and upland rice in particular competes poorly with weeds as uncontrolled weed growth often resulted in 28 to 100% yield loss (Johnson, 1996). Zhang (2001) reported that, in China, 10 million tonnes of rice are lost annually due to weed competition and such a quantity of rice is sufficient to feed at least 56 million people for one year. The amount of rice yield loss varies for example in West Africa it is 70 to 100% (WARDA, 1984) and 80 to 100% in Nigeria (Kehinde, 2002). Weeds have been ranked only second to drought stress in reducing upland rice grain yield and quality (De Datta, 1972). Therefore, weed management is one of the key elements to upland rice production.

Mechanical weed control using the hoe and hand weeding is the most common method used by upland rice farmers in Nigeria which has several disadvantages. Hand weeding is more complicated by the morphological similarity between rice and grass weed seedlings. Cultural methods of weed control such as crop spacing and use of competitive varieties, to suppress weeds might substantially reduce herbicide use and labour costs. Gibson et al. (2001) observed that the use of rice cultivars to suppress weeds is an important tool in weed management in rice; however, research on competitive cultivars of rice has been limited. They further noted that the use of competitive cultivars in an integrated weed

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Table 1. Characteristics of NERICA 1 and FARO 46 used for the study.

Characteristic	NERICA 1	FARO 46
Blast diseases	Resistant	Resistant
Soil aridity/acidity	Resistant	Susceptible
Lower leaves	Wide, droopy	Narrow, erect
Tillering capacity	10-15	9-12
Plant height (cm)	110-105	85- 100
Duration (days)	100-105	95-105
Maturity	early	early
Average grain yield (t ha^{-1})	3-4	2.5-3.0

Table 2. Physico-chemical properties of experimental soil in 2007 and 2008 seasons.

Soil characteristic	2007	2008
Chemical		
pH (H_2O)	5.7	5.9
Organic matter (g kg^{-1})	16.3	15.2
Available P (mg $kg^{-1)}$	12.97	15.26
CEC (cmo1kg^{-1})	10.6	9.8
Physical		
Sand (%)	41.4	42.8
Silk (%)	2.3	2.0
Clay (%)	56.3	55.2
Textural class	clay loam	clay loam

management programme may also be a cost-effective approach for reducing the selective pressure for resistance as competitive cultivars allow lower herbicide rates to be used. Also, Ferrell et al. (2006) observed that crop competition is one of the most important, but often one of the overlooked tools in weed control. Cultivar weed competitiveness is a function of weed tolerance, or the ability to maintain high yields despite weed competition, and weed suppression ability, is the ability to reduce weed growth through competition (Jannink et al., 2000). Haefele et al. (2004) observed rice cultivar differences in weed competitiveness and the cultivars that compete well against weeds are often thought to be tall, rapid early growth, droopy leaves and high specific leaf area. Therefore the objectives of the current study were to determine:

(1) The weed suppression ability of inter- and intra-specific rice varieties, and

(2) The effects of different weed control practices on the growth and yield of the two rice varieties.

MATERIALS AND METHODS

A field trial was conducted during the 2007 and 2008 cropping seasons at National Cereals Research Institute (NCRI), Badeggi (9°04N and 6°07E) in the Southern Guinea Savanna eco logical zone of Nigeria to compare the weed suppression ability of inter- and intra-specific upland rice varieties. The location was characterized by annual rainfall of 1187.5 mm and average temperature of about 33.5°C while the mean relative h umidity was 85.9%. The soil was hydromorphic in nature with gentle slope surface area.

The trial was laid out in a split plot design with two varieties of rice NERICA 1 (inter-specific variety) and FARO 46 (intra-specific variety) (Table 1) assigned to the main plot while seven weed control treatments (hoe weeding (HW) once at 25 or 45 days after sowing (DAS), twice at 25 and 45 DAS, thrice at 25, 45 and 65 DAS, application of orizo plus® (commercial mixture of 3,3-dichloropropionanilide + 2,4-dichlorophenoxy acetic acid) by Candel at 3.5 kg a.i ha^{-1} at 25 DAS, HW at 25 DAS followed by orizo plus® at 3.5 kg a.i ha^{-1} at 45 DAS and the control weedy-check) constituted the sub-plots. The treatments were randomly assigned and replicated three times.

The main plot size was 28 m × 6 m (168 m^2) with 0.5 m spacing between plots and 1 m between blocks while the sub-plot was 4 m × 6 m (24 m^2). The land was mechanically ploughed, harrowed and leveled and the seeds which were obtained from National Cereals Research Institute, Badeggi were sown on 27 July, 2007 and 11 July, 2008 on flat land. Five seeds were sown per hole at a spacing of 20 × 20 cm and later thinned to four seedlings per stand. Soil samples were taken diagonally after land preparation, but before seeds were sown from ten spots within the experimental site using soil auger at a depth of 15 cm and bulked for physical and chemical analysis. The surface soil horizon (0 to 15 cm) had low CEC, high organic matter content and moderately acid soil reaction. The soil texture was clay loam (Table 2).

The fertilizer used was 80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1} in

Table 3. Effects of rice varieties and weeding regimes on weed dry matter g m^{-2} in 2007 and 2008 seasons.

Treatment	25 DAS			45 DAS			65 DAS			85 DAS		
	2007	2008	combine	2007	2008	combine	2007	2008	combine	2007	2008	combine
Variety (V)												
NERICA 1	59.0	72.0	65.5	162.2	133.4	136.1	156.1	158.9	157.5	293.2	252.8	257.0
FARO 46	54.9	66.8	60.9	238.8	154.6	158.4	183.0	183.4	183.2	289.5	264.5	277.0
SE ±	NS	NS	NS	2.9	3.9	3.1	7.4	8.4	4.8	14.5	12.2	NS
LSD(0.05)	NS	NS	NS	8.7	11.9	8.9	22.4	25.5	26.2	NS	NS	NS
Weeding regime(WR)												
HW at 25 DAS	66.9	68.0	67.4	41.5	42.5	42.0	296.8	296.5	296.6	365.3	360.1	362.7
HW at 45 DAS	67.3	68.2	67.7	418.0	394.9	406.4	172.5	159.2	165.8	352.6	349.4	351.0
HW at 25 and 45 DAS	48.7	91.2	69.9	38.7	40.2	39.4	33.2	33.1	33.2	98.7	100.4	99.5
HW at 25, 45 and 65 DAS	65.0	62.3	63.6	37.6	37.7	37.7	33.4	33.8	33.6	24.3	25.0	24.7
Orizo plus at 25 DAS	50.0	71.3	60.7	25.2	35.4	30.3	124.7	117.6	121.1	227.0	240.8	233.9
HW at 25 DAS + Orizo plus at 45 DAS	36.7	62.7	49.7	46.8	40.6	43.7	34.7	32.1	31.9	197.1	88.0	86.7
Weedy check	64.4	62.0	63.3	445.8	416.6	431.2	494.4	526.0	530.4	774.4	648.8	710.6
SE ±	NS	NS	NS	26.8	12.4	20.5	15.8	14.3	47.4	52.3	31.8	18.0
CV (%)	59.6	49.54	12.8	8.8	15.5	13.8	20.0	22.5	18.1	37.9	21.6	22.9
LSD(0.05)	NS	NS	NS	82.6	47.7	63.3	48.7	59.4	52.8	161.0	69.2	55.3
V × WR	NS	NS	NS	*	*	*	NS	NS	*	NS	NS	NS

NS – not significant, * - significant at P ≤ 0.05, DAS – days after sowing and HW – hoe weeding.

the form of urea (46% N); single superphosphate (18% P_2O_5) and Muriate of potash (60% K_2O). The N was applied in two doses; the first at sowing, while the second was at panicle initiation stage. P and K were applied at planting by broadcasting. Weeding was done at different intervals using hoe and herbicide according to the treatments. Two men were engaged to scare away birds between 6 am to 6 pm daily during the milky stage to hard dough stage. Harvesting was done manually using sickle to cut the stem of the rice plants a few centimeters away from the ground level and the harvested rice was left in the field for four days for further drying before threshing. The harvested rice from each plot was threshed by beating the panicles against wooden planks on a tarpaulin then winnowed and bagged separately.

Weed dry matter was taken at 25, 45, 65 and 85 DAS by throwing 1 m^2 quadrant in each plot, and the weeds inside it were uprooted and dried to constant weight for weed dry matter determination. Similarly, rice tiller count was taken from 1 m^2 quadrant at 25, 45, and 85 DAS. The number of rice panicles m^{-2} was also taken from 1 m^2 quadrant (averaged over 3-quadrants thrown at random) at 100 DAS. Rice grain yield was obtained from the net plot and the grain was weighed using weighing balance and converted to tonnes per hectare.

All data collected were subjected to analysis of variance (ANOVA) and significant means were separated using Least Significant Difference (LSD) at 5% probability.

RESULTS

Weed dry matter production

The weed dry matter obtained was significantly influenced by rice varieties at 45 to 85 DAS in both years of the study and across the years such that it was higher in plots sown with FARO 46 than NERICA 1, except at 85 DAS in 2007 when reverse was the case (Table 3). Weed dry matter was significantly affected by weed control treatments at all sampling periods, except at 25 DAS in both years of the study. At 45 DAS, the use of orizo plus® gave a significant lower weed dry matter than hoe weeding at 45 DAS and the weedy check, but statistically similar to other treatments in both years of the study. As the season progressed to 65 DAS, significant lower weed dry matter was recorded in hoe weeding at 25 DAS followed by orizo plus® at 45 DAS which

Table 4. Interaction effects of rice varieties and weeding regimes on weed dry matter g m^{-2} in 2007 and 2008 seasons.

Treatment	45 DAS			65 DAS
	2007	2008	Combine	Combine
NERICA 1				
HW at 25 DAS	40.9	38.6	39.7	266.2
HW at 45 DAS	369.0	347.9	358.5	132.1
HW at 25 and 45 DAS	34.3	33.9	34.1	29.8
HW at 25, 45 and 65 DAS	31.3	30.6	31.0	28.8
Orizo plus at 25 DAS	24.5	37.9	31.1	166.7
HW at 25 DAS + Orizo plus at 45 DAS	47.5	42.7	44.9	24.4
Weedy check	424.8	402.1	413.4	504.3
FARO 46				
HW at 25 DAS	42.1	46.5	44.3	327.1
HW at 45 DAS	466.9	441.8	454.3	199.3
HW at 25 and 45 DAS	43.0	46.6	44.8	36.5
HW at 25, 45 and 65 DAS	43.9	44.8	44.4	38.3
Orizo plus at 25 DAS	26.1	33.0	29.6	125.6
HW at 25 DAS + Orizo plus at 45 DAS	46.5	38.5	42.5	39.3
Weedy check	466.8	431.1	448.9	516.1
SE ±	2.8	3.9	13.8	4.8
CV	8.8	12.4	8.3	18.1
LSD(0.05)	26.4	31.4	28.7	43.6

DAS – days after sowing, HW – hoe weeding.

was at par with two and three hoe weeding than the other four treatments in both seasons and across the years. At 85 DAS the lower weed dry matter was recorded in plots hoe weeded thrice in both seasons and their mean than all other treatments, except two hoe weeding in 2007, and hoe weeding at 25 DAS followed by application of orizo plus® at 45 DAS in 2008.

There was significant interaction between rice variety and weed control treatments on weed dry matter at 45 DAS in both years of the study and across the years and the mean at 65 DAS (Table 3). At 45 DAS, significant lower weed dry matter were obtained in all the treatments in 2007, 2008 and across the years, except when NERICA 1 and FARO 46 rice varieties were weeded at 45 DAS and the weedy control (Table 4). As the season advanced, the mean weed dry matter at 65 DAS shows significant lower weed dry matter in both rice varieties when they were hoe weeded twice or thrice and at 25 DAS followed by orizo plus® at 45 DAS than all other treatments.

Rice tiller production

Rice tillering capacity was significantly influenced by variety at all the sampling periods such that NERICA 1 was more prolific than FARO 46 (Table 5). The number of rice tillers m^{-2} was significantly affected by the different weed control treatments at all the sampling periods, except at 25 DAS (Table 5). Higher number of rice tillers were obtained at 45 DAS from three hoe weeding, which was statistically similar to those in one hoe weeding, two hoe weeding in both seasons and across the years than other weed control treatments, except plots hoe weeded at 25 DAS followed by orizo plus® at 45 DAS. At 100 DAS, three hoe weeding maintained significant higher number of tillers similar to two hoe weeding in both seasons and across the years, and one hoe weeding at 25 DAS in 2008 than other weed control treatments.

The interaction of rice variety and weed control treatments was significant at 45 and 100 DAS in 2008 and the mean (Table 5). The rice variety NERICA 1 produced greater number of tillers at 45 DAS when it was hoe weeded thrice which was similar to twice hoe weeding and one hoe weeding at 25 DAS followed by orizo plus® at 45 DAS than other weed control treatments in its counterpart variety (Table 6).

Rice panicle production

Panicle production was significantly influenced by the interaction between variety and weed control treatments in both seasons (Table 7). The rice variety NERICA 1

Table 5. Effects of rice varieties and weeding regimes on number of rice tillers m^{-2} in 2007 and 2008 seasons.

Treatment	25 DAS			45 DAS			100 DAS		
	2007	2008	combine	2007	2008	combine	2007	2008	combine
Variety (V)									
NERICA 1	144.4	152.8	148.6	215.0	212.8	213.9	235.9	245.4	240.0
FARO 46	119.8	119.6	119.7	176.6	179.7	178.2	222.7	222.3	223.0
SE ±	5.1	5.7	3.3	5.7	3.1	3.3	NS	7.0	4.32
LSD(0.05)	15.4	17.4	9.3	17.3	9.3	9.4	NS	21.1	12.3
Weeding regime(WR)									
HW at 25 DAS	130.3	129.2	129.8	228.5	260.3	244.4	266.2	299.2	282.7
HW at 45 DAS	126.0	131.2	128.6	143.2	131.3	137.3	186.0	167.8	176.9
HW at 25 and 45 DAS	149.0	153.0	151.0	258.8	257.2	258.0	320.5	320.3	320.4
HW at 25, 45 and 65 DAS	146.8	158.8	152.8	269.3	262.8	266.1	333.3	327.6	331.5
Orizo plus at 25 DAS	108.7	113.3	111.0	129.7	119.0	124.3	155.8	142.3	149.1
HW at 25 DAS + Orizo plus at 45 DAS	125.0	126.5	125.8	215.8	222.8	219.3	237.5	274.3	257.6
Weedy check	138.8	141.2	140.0	125.2	120.7	123.0	103.7	105.3	105.3
SE ±	NS	NS	NS	13.0	9.7	10.0	17.2	11.9	13.3
CV %	17.7	19.3	15.7	13.4	7.2	10.8	10.2	13.6	12.1
LSD(0.05)	39.0	39.3	38.0	40.1	29.9	30.7	52.8	36.0	40.9
V × WR Interaction	NS	NS	NS	NS	*	*	NS	*	*

NS –not significant, * - significant, at $p \leq 0.05$, DAS – days after sowing and HW – hoe weeding.

Table 7. Interaction effect of rice varieties and weeding regimes on panicle number and grain yield in 2007 and 2008 seasons.

Treatment	Panicle number (m^{-2})			Grain yield (Ton ha^{-1})		
	2007	2008	Combine	2007	2008	Combine
NERICA 1						
HW at 25 DAS	74.3	76.0	75.1	1.7	1.7	1.7
HW at 45 DAS	49.7	50.3	50.0	0.9	0.8	0.9
HW at 25 and 45 DAS	94.0	50.7	72.4	3.0	2.9	2.9
HW at 25, 45 and 65 DAS	95.7	95.7	95.7	3.1	3.2	3.1
Orizo plus at 25 DAS	49.7	50.7	50.2	1.9	1.9	1.9
HW at 25 DAS + Orizo plus at 45 DAS	62.3	73.0	67.7	2.6	2.6	2.6
Weedy check	44.8	18.0	31.4	0.3	0.2	0.3
FARO 46						
HW at 25 DAS	53.7	55.0	54.4	1.2	1.3	1.3
HW at 45 DAS	66.0	66.3	66.2	1.0	1.0	1.0
HW at 25 and 45 DAS	81.7	41.7	61.7	2.3	2.2	2.2
HW at 25, 45 and 65 DAS	82.0	82.0	82.0	2.3	2.5	2.4
Orizo plus at 25 DAS	44.0	41.7	42.9	1.3	1.2	1.3
HW at 25 DAS + Orizo plus at 45 DAS	56.7	67.0	61.9	2.0	2.1	2.1
Weedy check	26.0	33.0	29.5	0.5	0.4	0.4
SE ±	3.0	3.0	3.0	0.09	0.04	0.04
CV %	8.4	8.3	8.3	2.4	3.9	3.2
LSD(0.05)	9.1	9.2	9.2	0.07	0.1	0.09

DAS – days after sowing, HW – hoe weeding.

gave a significant higher number of panicles at three hoe weeding treatment which was at par with two hoe weeding in 2007 only than FARO 46 and other weed control treatments.

Rice grain yield

Rice grain yield was significantly affected by the interaction between rice variety and weed control treatments in both seasons in such away that higher rice grain yield was obtained from NERICA 1 hoe weeded thrice followed by two hoe weeding treatment compared to FARO 46 and other weed control treatments (Table 7). However, FARO 46 was more weed tolerant than NERICA 1.

DISCUSSION

Both chemical and physical properties of the soil of the experimental site were suitable for the production of upland rice. That notwithstanding, the crop was fertilized to boost its growth and yield and the clay loam soils are characterized by high available water holding capacity which is favourable for upland growth.

The insignificant differences in weed dry matter at 25 DAS could be because rice plants had not developed enough vegetation to form canopy for interference with the growth of weeds as reported by Suzuki et al. (2002) that competition of rice with weeds increases with time. Fischer et al. (2001) also observed that rice varieties did not have effect on weed growth till 45 DAS while Adeosun (2008) reported that the critical period of weed interference between rice and weeds is between 42 and 56 DAS.

The lower weed dry matter observed in plots of NERICA 1 variety at 45 DAS (Table 1) might be due to its morphological characteristics such as rapid early growth, drooping leaves, good tillering ability and high specific leaf area that confer weed suppression and competitive ability (Haefele et al., 2004). This is in line with the findings of Ekeleme et al. (2008) who reported lower weed dry weight in the NERICAs than other rice varieties. Johnson (1996) also reported tillering ability, height, leaf canopy and root development as important factors in determining the competitive ability of rice with weeds as we observed in NERICA 1 (Table 1).

The consistent similar low weed dry weight recorded in three hoe weeding, two hoe weeding and hoe weeding at 25 DAS followed by orizo plus® at 45 DAS might be due to better and sustained weed control in these plots. Our results are similar to that of Moynul et al. (2003) that lower weed dry matter was recorded in three, which was similar to two weeding treatments. Similarly, Sathyamoorthy et al. (2004) noted that three hand weeding gave a significantly lower weed dry matter which was comparable to the use of herbicide followed by one or two hand weeding at 35 or 55 DAS, respectively.

The results of rice tiller production show that it was significantly higher in NERICA 1 than FARO 46 in both seasons agreeing with the work of Moynul et al. (2003) who observed differences in tiller production in five rice varieties. The insignificant tiller production observed at 25 DAS might be due to the crop growth which was still at the seedling stage at that time. The lower number of tillers obtained in rice plots where orizo plus® was applied might be due to effects of herbicide on the plants, in consonance with the observations of Mitra et al. (2005). The consistent significant higher tiller production obtained from plots hoe weeded twice or thrice in both years of the study and across the growing season is attributable to greater efficient weed control thereby allowing the rice plants to develop well. This is in line with the work of Mitra et al. (2005) who observed higher number of rice tillers in weed - free treatment which was similar to two hand weeding treatment.

The significant higher panicle production in NERICA 1 hoe weeded thrice could be due to reduced weed competition that ensured efficient utilization of growth resources. This result is in line with the findings of Ekeleme et al. (2008) who observed significant higher spikelet (panicles) from the NERICAs in weeded plots than other rice varieties tested. Moynul et al. (2003) and Mitra et al. (2005) also observed that rice panicle production was higher in weed - free condition, which was statistically identical to two and three weeding regimes.

The significant higher grain yield recorded in NERICA 1 hoe weeded thrice was due to less weed competition that ensured better growth resource utilization in addition to higher number of tillers and panicles which are attributes of yield. The result is in consonance with the findings of Moynul et al. (2003) and Mitra et al. (2005) who reported higher grain yield from weed-free condition than other treatments.

Conclusion

The study has shown that rice varieties differ in their weed suppressing ability. The drooping leaves and higher tillering ability of NERICA 1 resulted in good canopy formation which contributed to its weed suppressing ability which translated into greater grain yield. The results also suggest that different weed control treatments greatly affected the weed control efficacy, yield contributing characters and grain yield of upland rice. Higher grain yield was obtained from three or two hoe weedings, as well as application of orizo plus® followed by supplementary hoe weeding at 45 DAS.

We recommend that for optimum weed suppression and higher grain yield cultivation of rice variety NERICA 1 with hoe weeding twice at 25 and 45 DAS or in addition to 65 DAS will be required.

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