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Full Length Research Paper

Evaluation of the relative weed competitiveness of upland rice varieties in Sierra Leone

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In Sierra Leone, weed management in upland rice production is a major constrain and yields are seriously reduced. Studies were conducted during the wet cropping season of 2007 and 2008 at Rokupr Agricultural Research Centre (RARC) in the upland ecology to assess the competitiveness of different rice varieties and to identify plant parameters responsible for their competitiveness. The results indicated that rice varieties differed in their competitiveness against weeds. Average yield losses ranged from 23 to 63% in 2007 and from 22 to 66% in 2008. Leaf area index (LAI) and tiller number with the exception of plant height correlated positively with competitiveness. The varieties NERICA 1, NERICA 6 and WAB 515-B-16A2.6 were found to be competitive and productive, whilst Buttercup (the local variety) though competitive but not productive. ROK 3 was the worse competitor but yielded similarly as NERICA 6 under weed -free conditions. The varieties NERICA 1, NERICA 6 and WAB 515-B-16A2.6 have potential in breeding programmes to increase their competitiveness without significantly compromising yields since they are both high yielding and competitive.

Key words: Varieties, competitiveness, LAI, tillers, yield, plant height, weed-free.

INTRODUCTION

Management of weeds in upland rice production is a major constrain and is expensive (Fischer et al., 2001). In Sierra Leone, about 4.2 ml ha of upland rice are grown and accounts for 70% of the rice production in the country (MAFFS, 2005). Upland rice is grown under diverse management conditions and is mainly slash-and-burn techniques. The method of weeding is hand pulling and this makes weed control in the uplands to be labour intensive and many a times not satisfactorily executed. As a result, yields in farmers' fields are low (0-0.8 t ha^{-1}) whilst in researchers' fields averaged 1.3 to 2.5 t ha^{-1} (MAFFS, 2005). Although the impact of weeds on rice production is well recognized, it has not been addressed by breeding programmes as have diseases and pests (Fischer et al., 1997).

The identification and development of competitive rice varieties may be more effective in weed suppression and provide a tool for integrated weed management (Fischer et al., 2001; Caton et al., 2003). Contrary to other weed control methods, improved varieties have proven well for ease of adoption. In view of this, weed-competitive upland rice varieties known as NERICA (New Rice for Africa) have been developed in West Africa for areas where herbicides are too expensive or unavailable. Differences in competitiveness amongst varieties have long been established. In Asia, Garrity et al. (1992) found up to 75% differences in weed suppression among varieties. Fischer et al. (1997) observed yield losses ranging from 27 to 60% among Latin American irrigated rice varieties growing in competition with Jungle rice. Gibson et al. (2001) found that the more competitive water-seeded rice varieties in their study required lower herbicide rates to achieve the same level of control of late water grass than the less-competitive varieties. The development of competitive rice varieties requires the identification of key plant parameters conferring competitive ability that can be used as selection criteria by breeders (Pester et al., 1999). This research was therefore carried out to assess the competitiveness of different rice varieties and to

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Abbreviations: NERICA, The new rice for Africa; **LAI,** leaf area index; **DAE,** days after emergence.

identify plant parameters conferring competitive ability under weedy and weed-free field conditions.

MATERIALS AND METHODS

Field experiments were conducted in the wet cropping season of 2007 and 2008 in the upland ecology at RARC in the Northwestern region of Sierra Leone on sandy loam soil having 4.8% organic matter, 1.98% C, 0.12% N, 4.00 ppm P, 7.20 ppm Fe, 70% aluminum saturation and a pH of 5.0. Rainfall was 2350 mm in 2007 and 2225 mm in 2008. Upland rice varieties that differ in morphological characteristics were evaluated. The varieties comprises of two new rice for Africa (NERICA), two Inter-specifics, one (1) Rokupr release variety and one Local.

The first four varieties are developed at the West African Rice Development Association (WARDA, 2001) now called Africa Rice centre (ARC). These varieties are short (85-100 cm), highly tillered with LAI between 5 to 8. ROK3 is the Rokupr release variety. It is intermediate in height (120- 125 cm), highly tillered with LAI between 4- 7, whilst butter cup, a local variety that is widely grown by farmers in Sierra Leone is tall (greater than 125 cm), moderately tillered with LAI 3-4 and very leafy with excessive vegetative growth. Varieties (Cultivars) and two competition levels (systems) consisting of rice only (weed-free) and rice associated with weeds (competition) were main factor treatments within a randomized complete block design with three replications. Weed-free plots were obtained thorough land preparation and spraying of herbicide, dual gold with active ingredient of 960 g l^{-1} S-metolachlor at the rate of 1.0 kg ha^{-1} during land preparation. Seeds of rice varieties were sown into 18 m^2 each by drilling into rows 20 cm apart at 80 kg ha^{-1}. Fertilization at the rate of 80-40-40 using NPK 15-15-15 compound fertilizer was broadcast and covered when the rice was drilled. At 40 days after emergence (DAE), 40 kg ha^{-1} N (nitrogen) was top dressed. Two sample quadrants of 1 m^2 each were used to collect data on ten plants per sample, means for plant height, tiller number at 40 DAE, and at harvest, were obtained. Weed biomass was collected at harvest from weedy plots. LAI for rice varieties was determined at 40 DAE by taking the length and breadth of each leaf blade in 10 different tillers randomly selected form the sample quadrants. The mean number of leaves/tiller and total number of tillers within the quadrants were recorded. These series of information were then used to calculate the leaf area index (LAI), using the relation according to Yoshida (1981):

LAI= k[(Total number of tillers× Average leaf area × Number of leaves per tiller)/(Area of land covered by the total number of tillers(100 cm× 100 cm)], Where K = 0.75

Rice grain was hand-harvested at maturity and grain yield of rice in kg ha^{-1} was calculated at 14% moisture content. Analysis of variance (ANOVA) was carried out for grain yield and growth parameters. Correlation analysis for variety (cultivar) means (Wortman, 1993) was used to relate plant parameters to competitiveness and yield whilst the variance component (Fischer et al., 1997) was used to assess the advantage of screening for competitiveness under weedy versus weed- free conditions. According to Fischer et al. (1997) the variance component was simplified as follows:

$$S^2v = 0.5\{0.5(S_m-S_c)^2 + S_mS_c(1-r_{mc})\},$$

Where S_m and S_c are the genotypic standard deviations in monoculture (weed-free) and competition, respectively, and r_{mc} is the genotypic correlation for both environments. These parameters were estimated using the ANOVA results. The second term of the variance $\{S_mS_c(1-r_{mc}\}$ predominates when varietal performance in weed–free plots differs from that in weedy plots (competition).

RESULTS AND DISCUSSION

Weed competition reduced grain yield of rice varieties (Table 1) and the reductions were positively correlated with weed biomass for both years (r = 0.96 in 2007 and r = 0.99 in 2008) at $p < 0.01$ for both years. Average yield losses ranged from 22 to 66%. This shows that rice varieties behave differently in their competitiveness to suppress weeds under severe competition. There was a positive relationship between competition (calculated as yield in competition/yield in weed-free plots) and yield potential. Under weedy conditions, the best competitors were NERICA 1, NERICA 6, WAB 515-B-16A2.6 and Buttercup for both years. The worse competitors were WAB 570-10-B-1A2.6 and ROK 3. Under weed-free conditions, the yield of the worse competitor (ROK 3) was similar to NERICA 6 for both years (Table 1). Similar work done by Garrity et al. (1992) and in IRRI (1994) showed 75% differences in the competitiveness of upland rice. The varieties NERICA 1, NERICA 6 and WAB 515-B-16A2.6 have potential in breeding programmes to increase their competitiveness without significantly affecting yields since they are both high yielding and competitive. Similar findings have been documented by Garrity et al. (1992). However, according to Tanaka et al. (1966), yield potential and competitiveness should not be considered as independent, since plant morphology can affect both.

Growth parameters

Table 2 shows the analysis of variance for grain yield and growth parameters of rice growing in two systems (weed-free and competition) with the variance components analysis at 40 DAE and harvest from Table 2. There is evidence that the key growth parameters conferring competitive ability are tiller numbers and leaf area index (LAI). Analysis of variance shows significant for tiller numbers at 40 DAE and at harvest and for LAI at 40 DAE for system and cultivar (variety). Plant height at 40 DAE was not significant but became significant at harvest.

This indicates that competition affected rice heights only at late growth stages. Similar studies conducted by Fischer et al. (1997) revealed similar studies and attributed this to modern rice plant types which have erect leaves that allow good light penetration deep into the canopy. Also, plants in competition were elongated and their heights similar to those in weed-free plots. Hence, height would not be a parameter for enhancing competitiveness. In other studies involving different

Table 1. Yield (kg ha^{-1}) of rice varieties in weed-free and in competition.

Rice variety	2007					2008				
	Weed-free grain yield (kg ha^{-1})	In competition grain yield (kg ha^{-1})	% Reduction	Weed biomass (g m^{-2})	Competitiveness	Weed-free grain yield (kg ha^{-1})	In competition grain yield (kg ha^{-1})	% Reduction	Weed biomass (g m^{-2})	Competitiveness
NERICA 1	2434	1765	27	15.2	0.73	2257	1563	31	18.1	0.69
NERICA 6	2657	2031	24	14.9	0.76	2569	1901	26	15.4	0.74
WAB 570-10-B-1A2.6	2554	1408	45	56.4	0.55	2356	1208	46	52.8	0.51
WAB 515-B-16A2.6	2540	1942	23	15.8	0.77	2240	1642	27	17.3	0.73
ROK 3	2690	1007	63	67.9	0.37	2639	907	66	80.2	0.34
Buttercup	1886	1406	25	16.0	0.75	1789	1395	22	14.3	0.78
Mean	2460	1593				2308	1436			
Std. error	108.8	108.8	3.1	4.9	0.16	100.2	100.2	4.5	4.1	0.12
CV (%)	5.4	5.4	8.9	15.8	24.8	5.5	5.5	12.9	12.3	19.0

Table 2. Analysis of variance (ANOVA) and the variance component analysis for growth parameters of rice (in weed-free and in competition) and rice grain yield (kg ha^{-1}).

Growth parameter	2007		2008	
	40 DAE	At harvest	40 DAE	At harvest
Height				
System (S)	NS	**	NS	**
Variety (V)	**	**	**	**
S x V	NS	NS	NS	NS
Complex Var C, %				
Tiller number				
System (S)	**	**	**	**
Variety (V)	**	**	**	**
S x V	**	**	**	**
Complex Var C, %	73	62	88	39
Leaf area index (LAI)				
System (S)	**		**	
Variety (V)	**		**	

Table 2. Contd.

S x V	**		**	
Complex Var C, %	94		90	
Rice grain yield (kg ha^{-1})				
System (S)		**		**
Variety (V)		**		**
S x V		**		**
Complex Var C, %		85		95

* Significant at 0.05 probability level; ** Significant at 0.01 probability level; NS, Not significant.

Table 3. Correlation coefficients between rice grain yield (in weed-free) and growth parameters (in weed-free) at 40 DAE and at harvest.

Growth parameter	Relative rice yield (weed-free) 2007		Relative rice yield (weed-free) 2008	
	40 DAE	At harvest	40 DAE	At harvest
Height	-0.52 NS	-0.66 NS	- 0.35 NS	-0.46 NS
Tiller number	0.81**	0.85**	0.80**	0.89**
Leaf area index (LAI)	0.89**		0.89**	

plants types, it was concluded that tall, vigorous and leafy varieties have been more competitive than short plant types with erect leaves (Jennings and Herrera, 1968). Tanaka et al. (1966) demonstrated that large and competitive varieties have low yield potential. Thus, yield potential and competitiveness appear as conflicting. In these studies, no negative correlations (Table 3) were found between tiller number and LAI (weed-free) and weed-free yields, suggesting that there is prospect in competitiveness in highly productive varieties with no significant reduction in yields. However, the correlation coefficients of these parameters when in competition related poorly to rice competitiveness (Table 4). This further suggests that rice growth parameters were expressed differently in weed-free than in competition. This confirms previous studies of Fischer et al. (1997).

Table 2 showed that the analysis of variance for grain yield, tiller number and LAI to be significant for system (weed-free or in competition) or variety interaction (S × V). This indicates differences in varietal competitiveness in weed-free plots than in competition for parameters (Table 3). Plant height was not significant for S × V variance (Table 2) and hence a lack of correlation between parameter in weed-free and in competition (Table 3). These finding are in agreement with Fischer et al. (1997). Therefore, selection for tiller number and LAI could be efficient if conducted in competition rather than in weed-free plots alone.

Conclusion

Breeding to increase the competiveness of highly productive rice plant types would be possible without significantly affecting yields. The competitiveness observed in these studies for the varieties: NERICA 1, NERICA 6, and WAB 515-B-16A2.6 would be adequate to improving farmers'

Table 4. Correlation coefficients between rice grain yield (in competition) and growth parameters (in weed-free) at 40 DAE and at harvest.

Growth parameter	Relative rice yield (in competition) 2007		Relative rice yield (in competition) 2008	
	40 DAE	At harvest	40 DAE	At harvest
Height	-0.21 NS	-0.43 NS	-0.24 NS	-0.36 NS
Tiller no.	-0.19 NS	-0.21 NS	-0.34 NS	-0.27 NS
Leaf area index (LAI)	-0.30 NS		-0.30 NS	

Income and reduce herbicide use. Increasing LAI and tiller number will result in more competitive rice varieties but plant types with excessive mutual shading with vigorous vegetative biomass should be avoided. The variety ROK 3 though high yielding but not competitive, can be improved upon for its competitiveness. Breeding for resistant to weed competition should be conducted under weedy condition.

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