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Evaluation of the relative weed competitiveness of some lowland rice varieties in Sierra Leone.

S.S. Harding[1*] and A.B. Jalloh[2]

[1]Weed Scientist/ Agronomist, Rokupr Agricultural Research Centre, Soil Crop Animal and Natural Resource Management Programme, P.M.B. 736, Freetown, Sierra Leone.

[2]Plant breeder, Rokupr Agricultural Research Centre, Crop Improvement Programme, P.M.B. 736, Freetown, Sierra Leone.

Authors' contributions

This work was carried out by the two authors. SSH designed the study, performed the statistical analysis, wrote the protocol and first draft of the manuscript. ABJ assisted in the designed, description of rice varieties and also in the literature searches. The authors read and approved the final manuscript.

ABSTRACT

Weed management in lowland rice production is a major constrain leading to low yields. Studies were conducted during the wet cropping season of 2009 and 2010 at Rokupr Agricultural Research Centre (RARC) in the lowland ecology to assess the competitiveness of different rice varieties and to identify plant parameters associated with competitiveness. The results showed varietal differences in their competitiveness against weeds. Average yield losses ranged from 13 to 67 percent in 2009 and from 12 to 70 percent in 2010. With the exception of plant height, Leaf area index (LAI) and tiller number correlated positively with competitiveness. The varieties NERICA L19, NERICA L20 and WAS 57-B-B-17-3-3-6-TGR20 an Inter-specific were found to be good competitors and high yielding, whilst Buttercup (the local variety) though competitive was not productive. The varieties, NERICA L38 and ROK10 were the worse competitors but however, yielded similarly as NERICA L19 and NERICA L20 under weed-free plots. The varieties NERICA L38 and ROK10 though not competitive have the potential in breeding programmes to be improved upon for their competitiveness since they are high yielding.

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

Corresponding author: Email: sokih2003@yahoo.co.uk;* **Mobile No. +232 77 602 341 or +232 76 440 335

ABBREVIATIONS

DAT*: Days After Transplanting;* ***CV:*** *Coefficient of Variation;* ***LAI:*** *Leaf Area Index;* ***RARC****: Rokupr Agricultural Research Centre.*

1. INTRODUCTION

In Sierra Leone weed management in lowland rice production is a major constrain and is expensive (Fischer et al., 2001). In Sierra Leone, the total arable land under Mangrove and Inland Valley swamps cultivation is about 890 thousand hectares (MAFFS, 2005).

The common practice of weed control in these lowlands is hand pulling and this makes the practice to be labour intensive and many a times not satisfactorily executed. As a result, yields in farmers' fields are low (0.8 – 1.5 t ha^{-1}) whilst in well managed researchers' fields with the use of chemicals averaged 2.5 to 3.5 t ha^{-1} (Harding, et al., 2012). 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 lowland 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 Sierra Leone, Harding and Jalloh (2011) found up to 66% differences in weed suppression among upland rice varieties. Fischer et al. (1997) observed

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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 lowland rice varieties and to identify plant parameters in these new rice varieties conferring competitive ability under weedy and weed-free field conditions.

2. MATERIAL AND METHODS

Field experiments were conducted in the wet cropping season of 2009 and 2010 in the lowland ecology of the Mangrove Associated Swamp at RARC in the Northwestern region of Sierra Leone. Lowland rice varieties that differ in morphological characteristics were evaluated. The varieties comprise three New Rice for Africa (NERICA), one Inter-specific, 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. ROK10 is the Rokupr release variety. It is high yielding, longer in duration and is well adapted to this ecology and is the main variety grown by farmers. It is intermediate in height (120-125 cm), highly tillered with LAI between 4 to 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 (Harding and Jalloh, 2011). Six varieties and two competition levels (systems) consisting of rice only (weed-free) and rice associated with weeds (in competition)

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were main factor treatments (6 x 2) within a randomized complete block design with three replications. Weed-free plots were obtained by thorough land preparation and spraying of herbicide, RiceForce with active ingredient of 0.25 ha^{-1} oxadiazon at the rate of 3.8 l ha^{-1} during land preparation. Three weeks old Seedlings of rice varieties were transplanted into 18 m^2 plots each on the 28th and 30th of July in 2009 and 2010, respectively at a spacing of 20 cm within and between rows. Fertilization at the rate of 60-40-40 using NPK 15-15-15 compound fertilizer was broadcast two weeks after transplanting. At 40 days after transplanting (DAT), 20 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 DAT, and at harvest, were obtained. Weed biomass was collected at harvest from weedy plots. LAI for rice varieties was determined at 40 DAT by taking the length and breadth of each leaf blade in 10 different tillers randomly selected from 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 (ANOVAR) was carried out for grain yield and growth parameters using the MSTATC soft ware package.

The analysis for main factors was done separately for each year. Mean values from ANOVAR were then summarized and presented in table 1.

Correlation analysis for variety 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

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weedy versus weed-free conditions and presented in tables 2-4.

According to Fischer et al. (1997) the variance component was simplified as follows:

$S^2v = 0.5\{0.5(S_{wf}-S_w)^2 + S_{wf}S_w(1-r_{wf*w})\}$,

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

2.1 Description of Study Site and Choice of Varieties

The Mangrove Associated Swamp selected for this study was situated at the upper reaches of the main Mangrove Swamp catena and grade into the adjacent uplands. The Mangrove Associated Swamp has a salt free period of at least six months. These varieties selected are well adapted to this ecology and are mainly used by farmers. The ecology is influenced by seasonal flooding through seepage and/or runoff from the surrounding uplands; as well as by tidal water during spring tides at the peak of the rainy season in August. The annual rainfalls recorded were 3000mm and 3500mm for 2009 and 2010, respectively.

The soils of the Mangrove Associated are sufic tropaquept (cat clays) with a massive structural consistence. Soil reaction is acidic with pH range of 4.5-5.5; and is characterized by toxic levels of iron and aluminium (RARC, 2011). The soil fertility status is low with nitrogen and phosphorus being the major nutrient deficiencies.

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3. RESULTS AND DISCUSSION

Weed competition significantly reduced grain yield of rice varieties (Table 1) and the reductions were positively correlated with weed biomass for both years ($r = 0.95$ in 2009 and $r = 0.89$ in 2010) at $p < 0.01$ for both years. Average yield losses ranged from 12 to 70%. 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 L19, NERICA L20, WAS 57-B-B-17-3-3-6-TGR20 and Buttercup for both years. The worse competitors were NERICA L38 and ROK10. Under weed-free conditions, the yields of the worse competitors were similar to NERICA L19 NERICA L20 for both years (Table 1). Similar work done by Garrity et al. (1992) and in IRRI (1994) showed 75% differences in the rice competitiveness. The varieties NERICA L19, NERICA L20 and WAS 57-B-B-17-3-3-6-TGR20 have potential in breeding programmes and could be used to increase the competitiveness of highly productive varieties that are not 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 such as plant height, tiller production and leaf number and canopy can affect both.

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176 **Table 1. Yield (kg ha^{-1}) of rice varieties in weed-free and in competition in 2009 and 2010**

	2009					2010				
Rice variety	**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 L19	3988	3326	17	18.2	0.83	3563	3112	13	12.2	0.87
NERICA L20	3650	3187	13	16.3	0.87	3611	3176	12	13.1	0.88
WAS 57-B-B-17-3-3-6-TGR20	2996	2331	22	20.4	0.78	3121	2710	13	14.2	0.87
NERICA L38	3633	1455	60	34.7	0.40	3346	1349	60	36.3	0.40
ROK10	3574	1163	67	34.6	0.33	3175	963	70	44.7	0.30
Butter Cup	2317	1316	43	30.9	0.57	2024	1009	50	32.4	0.50
Mean	3360	2130				3140	2053			
Std. error	431	431	4.8	0.44	0.21	443	443	1.2	0.46	0.20
CV(5)	8.2	8.2	16.2	10.8	15.2	6.4	6.4	14.4	13.9	21.5

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3.1 Growth parameters

Table 2 shows the analysis of variance for grain yield and growth parameters of rice growing in two systems (weed-free and in competition) with the variance components analysis at 40 DAT and at harvest. 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 x V). From the table, there is evidence that the key growth parameters conferring competitive ability are tiller numbers and leaf area index (LAI). Analysis of variance shows significant at P=0.05 for tiller numbers at 40 DAT and at harvest and for LAI at 40 DAT for system and variety at P=0.05. Plant height at 40 DAT was not significant but became significant at harvest (P=0.05). This indicates that competition affected rice heights only at late growth stages. Plant height was also not significant for S x V variance and hence a lack of correlation between plant height in weed-free and in competition (Table3). 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.

Similar studies conducted by Fischer et al. (1997) revealed that plants in competition were elongated and their heights were similar to those in weed-free plots. Hence, height would not be a parameter for enhancing competitiveness. In other studies involving different 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.

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Table 2. Analysis of variance (ANOVAR) and the variance component analysis for growth parameters of rice (in weed-free and in competition) and rice grain yield (kg ha^{-1}) in 2009 and 2010

Growth parameters	2009		2010	
	40 DAT	At harvest	40 DAT	At harvest
Height				
System (S)	NS	NS	NS	**
Variety (V)	**	**	**	**
S x V	NS	NS	NS	NS
Complex Var C, %				
Tiller				
System (S)	**	**	**	**
Variety (V)	**	**	**	**
S x V	**	**	**	**
Complex Var C,	85	65	90	35
Leaf Area Index (LAI)				
System (S)	**		**	
Variety (V)	**		**	
S x V	**		**	
Complex Var C,	95		80	
Rice grain yield (kg/ha)				
System (S)		**		**
Variety (V)		**		**
S x V		**		**
Complex Var C,		80		80

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

In these studies, no negative correlations (Table 3) were found between tiller number and LAI (weed-free) and weed-free yields indicating differences in varietal competitiveness in weed-free plots and in competition for the said parameters. Table 3 further suggests that there is prospect in competitiveness for highly productive varieties. However, the correlation coefficients of these parameters when in competition related poorly to rice competitiveness (Table 4) suggesting that rice growth parameters were expressed differently in weed-free than in competition. This confirms previous studies of Fischer et al. (1997).

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Table 3. Correlation coefficients between rice grain yield (in weed-free) and growth parameters (in weed-free) at 40DAT and at harvest in 2009 and 2010

Growth parameters	Relative rice yield (weed-free) 2009		Relative rice yield (weed-free) 2010	
	40 DAT	At harvest	40 DAT	At harvest
Height	-0.48 NS	-0.55 NS	-0.25 NS	-0.66 NS
Tiller number	0.90**	0.88**	0.85**	0.78**
Leaf Area Index (LAI)	0.92**		0.84**	

Table 4. Correlation coefficient between rice grain yield (in competition) and growth parameters (in weed-free) at 40 DAT and at harvest in 2009 and 2010

Growth parameters	Relative rice yield (in competition) 2009		Relative rice yield (in competition) 2010	
	40 DAT	At harvest	40 DAT	At harvest
Height	-0.23 NS	-0.45 NS	-0.25 NS	-0.27 NS
Tiller number	-0.20 NS	-0.25 NS	-0.44 NS	-0.33 NS
Leaf Area Index (LAI)	-0.32 NS		-0.33 NS	

4. 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 L19, NERICA L20, and WAS 57-B-B-17-3-3-6-TGR 20 would be adequate to improving farmers' 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 varieties ROK10 and NERICA L38 that were both high yielding but not competitive, can be improved upon for their competitiveness. Breeding for tolerant to weed competition should be conducted under weedy condition.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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REFERENCES

Caton, B.P., Cope, E.A., Mortimer, M. (2003). Growth traits of diverse rice cultivars under severe competition: Implication for screening for competitiveness. In Field Crops Research 83: 157- 172.

Fischer, A.J., Ramirez, H.V., Lozano, J. (1997). Suppression of Junglerice [Echinochloa colona (L) Link] by irrigated rice cultivars in Latin America. Agron. J. 89: 516:521.

Fischer, A.J., Ramirez, H.V., Gibson, K.D., Da Silveira Pinheoro, B. (2001). Competitiveness of semi dwarf Upland Rice Cultivars against Palisadegrass (Brachiaria brizantha) and Signalgrass (B. decumbens). In Agron. J. 93: 967- 973.

Garrity, D.P., Movillon, M., Moody, K. (1992). Differential weed suppression ability in upland rice cultivars. Agron. J. 84: 586-591.

Gibson, K.D., Hill, J.E., Foin, T.C., Caton, B.P., Fischer, A.J. (2001). Water-seeded rice cultivars differ in ability to interfere with watergrass. Agron. J. 93: 326-332.

Harding, S.S., Jalloh, A.B. (2011). Evaluation of the relative weed competitiveness of upland rice varieties in Sierra Leone. African Journal of Plant Science Vol. 5(7), pp. 396-400.

Harding, S.S., Taylor, D.R., Jalloh, A.B., Mahmood, N., Dixon, C.A., Johnson, S.D. (2012). Evaluation of the Efficacy of Different Rates of Herbicides on Weed Growth and Grain Yield of Two Rice Varieties in Two Rice Ecologies in Sierra Leone. American Journal of Experimental Agriculture 2(4): 607-615.

International Rice Research Institute (1994). Programme report for 1993. IRRI, Los Banos, Laguna, Philippines. p. 23

Jennings, P.R., Herrera, R.M. (1968). Studies on competition in rice: 11. Competition in segregating population. Evolution 2: 332-336.

MAFFS (2005). Ministry of Agriculture Forestry and Food Security. Rice Research Station: Crop Production Guidelines for Sierra Leone. Pp. 3-8.

Pester, T.A., Burnside, O.C., Orf, J.H. (1999). Increasing crop competitiveness to weeds through breeding. In D.D Buhler (ed.) Expanding the context of weed management. Food production Press, Binghamton, NY. pp. 59-76.

RARC. (2011). Rokupr agricultural research centre, annual work programme review Conference. Freetown, Sierra Leone.

Tanaka A, Kawano K, Yamaguchi J (1966). Photosynthesis, respiration and plant type of the tropical rice plant. IRRI, Los Banos, Laguna, Philippines, pp. 5-7.

WARDA (2001). West Africa Rice Development Association: Bintu and her New Rice for Africa: Breaking the shackles of slash-and burn farming in the World's poorest region. (Winner of the CGIAR King Baudoun Award 2000).

Wortman CS (1993). Contribution of bean morphological characteristics to weed suppression. Agron. J. 85: 840-843.

Yoshida S (1981). Fundamentals of rice crop science. IRRI, Los Banos, Laguna, Philippines. p.10.

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