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

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**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 design, description of rice varieties and also in the literature searches. The authors read and approved the final manuscript.

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## ABSTRACT

Weed management in lowland rice production is a major constraint leading to low yields. Studies were conducted during the wet cropping seasons 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 experimental design was 6 x 2 factorial arranged in randomized complete block (RCBD) in three replications. Six rice varieties and two systems (weed-free and in competition) were evaluated. The results showed varietal differences in their competitiveness against weeds. Average yield losses ranged from 13 to 67 percent in 2009 and 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 low yielding. The varieties, NERICA L38 and ROK10 were the worse competitors but yielded similarly as NERICA L19 and NERICA L20 under weed-free plots.

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

**ABBREVIATIONS**

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

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## 1. INTRODUCTION

In Sierra Leone, the total arable land under Mangrove and Inland Valley swamps cultivation is about 890,000 hectares (MAFFS, 2005). Weed management in lowland rice production is a major constraint and is expensive (Fischer et al., 2001). The major rice weeds found in the lowlands of Sierra Leone are *Schyzachirium brevifolium, Panicum laxum, Acroceras zizaanioides, Echinochloa oryzoides,* and *Ischaemum rugosum.* These are classified as grasses. The common sedges are *Cyperus haspan, Cyperus difformis*, *Cyperus iria* and *Kyllinga pumila* and amongst the broad leaves are Clappertonia ficifolia, Commelina benghalensis, Dissotis verticillata, *Ludwigia decurrens, Ipomea aquatica* and *Mimosa pudica*. Losses due to weeds have been reported to be in range of 22 to 66% in the uplands (Harding and Jalloh, 2011) and 12 to 70% in the lowlands.

The common practice of weed control in lowland rice is hand pulling which 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 insect pests (Fischer et al., 1997).

The identification and development of competitive rice varieties may be 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 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 required lower herbicide rates to achieve the same level of control of late watergrass (*Echinochloa oryzoides*) 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). Plant traits such as tiller number and leaf area index have shown to confer competiveness and could be used in breeding programmes to enhance competiveness of

high yielding varieties that are not competitive (Fischer et al., 2001).

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 seasons 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 comprised three New Rice for Africa (NERICA), one Inter-specific, one Rokupr released variety (ROK 10) and one Local (Butter Cup). The first four varieties (NERICA L19, NERICA L20, WAS 57-B-B-17-3-3-6-TGR20 and NERICA L38) were 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 released variety. It is high yielding, longer in duration (170-180 days) 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 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) were laid out in a 6 x 2 factorial trial arranged in a randomized complete block design with three replications. Weed-free treatment plots were obtained by application of RiceForce (pre-plant herbicide) with active ingredient 250 grams per litre oxadiazon. It was applied at 3.8 litres per hectare on moist soil near saturation 14 days before transplanting. This was to ensure that plots remain completely weed-free. Three weeks old seedlings of rice varieties using two seedlings per stand were transplanted into 18 $m^2$ plots on the 28$^{th}$ and 30$^{th}$ 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 on moist soil near saturation by draining of standing water. At 40 days after transplanting (DAT), 20 kg per ha. N was top dressed. Two sample quadrats 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, sundried and weighed with a beam balance. 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 quadrats. The mean number of leaves/tiller and total number of tillers within the

quadrats 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.

Competitiveness according to Fischer et al. (1997) was calculated as: (yield in competition/yield in weed-free plots).

Rice grain was hand-harvested at maturity and grain yield of rice in kg per ha. was calculated at 14% moisture content.

Percentage reduction in rice yield according to Fischer et al. (1997) was calculated as: [(Weed-free – In competition)/Weed-free] x 100

Analysis of variance (ANOVA) was carried out for grain yield and growth parameters using the MSTATC soft ware package.

The analysis for factors was done separately for each year. Mean values from ANOVA 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 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 ANOVA 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 and has a salt free period of at least six months. The 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 (RARC, 2011).

## 3. RESULTS AND DISCUSSION

Weed competition significantly reduced grain yield of rice varieties (Table 1) and the reductions were positively correlated with weed biomass (r = 0.95 in 2009 and r= 0.89 in 2010) at $P < .001$ for both years. Average yield losses ranged from 12 to 70%. The higher the weed biomass (dry matter basis) the greater the percentage yield reduction (Table 1). 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 (Table 1). Under weedy conditions, the best competitors were NERICA L19, NERICA L20 followed by WAS 57-B-B-17-3-3-6-TGR20 in 2009. The varieties NERICA L19 and NERICA L20 were not statistically different from each other at $p < .001$. However, in 2010 the varieties NERICA L19, NERICA L20 and WAS 57-B-B-17-3-3-6-TGR20 when in competition performed significantly the same at $p = .05$. The performance of these varieties could be attributed to the less weed biomass (dry matter basis) observed due to their ability to suppress weed. The worse competitors were NERICA L38 and ROK10. However, under weed-free conditions, the yields of the worse competitors were significantly similar to NERICA L19 and NERICA L20 at $P = .05$ 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 Fischer et al. (1997), yield potential and competitiveness should not be considered as independent, since plant morphology such as plant height, tiller production, leaf number and canopy can affect both.

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**Table 1. Yield (kg ha$^{-1}$) of rice varieties in rice-weed 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 | | | |
| LSD (0.05) | 600 | 600 | 5.2 | 4.7 | 0.24 | 542 | 542 | 2.2 | 8.5 | 0.08 |
| CV (%) | 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. The Table 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). However, weed biomass was only significant for system and variety (Table 2). 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 significance at $P = .05$ for tiller numbers at 40 DAT and at harvest and for LAI at 40 DAT for system and variety at $P = .05$. Plant height at 40 DAT in 2010 was not significant but became significant at harvest ($P = .05$). This indicates that competition affected rice heights only at late growth stages. Plant height and weed biomass at harvest were not significant for S x V variance (Table 2) and hence a lack of correlation between plant height in weed-free and in competition (Table3). These findings 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.

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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 | | Significant for parameters | |
|---|---|---|---|---|---|---|
| | 40 DAT | At harvest | 40 DAT | At harvest | system | variety |
| **Height** | | | | | | |
| System (S) | NS | NS | NS | ** | In competition | NERICA L19, NERICA L20, |
| Variety (V) | ** | ** | ** | ** | | WAS 57-B-B-17-3-3-6-TGR20 |
| S x V | NS | NS | NS | NS | | Butter Cup |
| Complex Var C, % | | | | | | |
| **Tiller** | | | | | | |
| System (S) | ** | ** | ** | ** | Weed free | NERICA L19, NERICA L20, |
| Variety (V) | ** | ** | ** | ** | In competition | WAS 57-B-B-17-3-3-6-TGR20 |
| S x V | ** | ** | ** | ** | | Butter Cup |
| Complex Var C, | 85 | 65 | 90 | 35 | | |
| **Leaf Area Index (LAI)** | | | | | | |
| System (S) | ** | | ** | | Weed free | NERICA L19, NERICA L20, |
| Variety (V) | ** | | ** | | In competition | WAS 57-B-B-17-3-3-6-TGR20 |
| S x V | ** | | ** | | | Butter Cup |
| Complex Var C, | 95 | | 80 | | | |
| **Weed biomass** | | | | | | |
| System (S) | | ** | | ** | In competition | NERICA L19, NERICA L20, |
| Variety (V) | | ** | | ** | | WAS 57-B-B-17-3-3-6-TGR20 |
| S x V | | NS | | NS | | Butter Cup |
| Complex Var C | | | | | | |
| **Rice grain yield (kg/ha)** | | | | | | |
| System (S) | | ** | | ** | Weed free | NERICA L19, NERICA L20, |
| Variety (V) | | ** | | ** | In competition | WAS 57-B-B-17-3-3-6-TGR20 |
| S x V | | ** | | ** | | Butter Cup |
| Complex Var C, | | 80 | | 80 | | |

*significant at .05 probability level ** significant at .01 probability level; NS, Not significant

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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).

**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. The varieties ROK10 and NERICA L38 that were both high yielding but not competitive, can be improved upon for their competitiveness. Breeding for weed suppressive rice varieties should be conducted under weedy condition.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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