

Evaluation of the Efficacy of Different Rates of Herbicides on Weed Growth and Yield of Two Rice Varieties in Two Rice Ecologies in Sierra Leone.

S. S. Harding^{1*}, C. A. Dixon², A. B. Jalloh³, S. D. Johnson⁴ and N. Mahmood²

^{1*}Rokupr Agricultural Research Centre, Soil Crop Animal and Natural Resource Management Programme, P.M.B. 736, Freetown, Sierra Leone.

²Rokupr Agricultural Research Centre, Out-Reach, Programme, P.M.B. 736, Freetown, Sierra Leone.

³Rokupr Agricultural Research Centre, Crop Improvement Programme, P.M.B. 736, Freetown, Sierra Leone.

⁴Rokupr Agricultural Research Centre, Engineering, Post Harvest Technology and Nutrition Programme, P.M.B. 736, Freetown, Sierra Leone.

ABSTRACT

Two rice varieties, NERICA L19 (weed competitive) and ROK10 (high yielding) were subjected to two pre-emergence (RiceForce and ButaForce) and two post-emergence (Stam and RiceForce) with different active ingredients and rates of application during the wet seasons of 2009 and 2010 cropping seasons at Rokupr Mangrove Associated Swamp ecology and at Gbomsamba in the Boliland ecology to determine (i) the effectiveness of different rates of application of pre-and post-emergence herbicides on weed growth and yield of rice varieties, (ii) identify suitable herbicides for the two ecologies and (iii) the cost benefit of herbicides application. The results showed that weed population was significantly reduced with the application of different herbicides. Percentage reduction in weed population over control ranged from 65 for RiceForce (PE) to 91 percent for Stam (PE) in 2009 and from 68 for RiceForce (PE) to 87 for ButaForce (Pe) in 2010. The herbicides Stam (PE), RiceForce (Pe) and ButaForce (Pe) were the most effective in reducing weed population in both ecologies in both years. All herbicides treatments gave significantly higher grain yields than control plots. Grain yields of plots increased with increased rates of application but yields from full and three-quarter doses were similar. Yields of the two varieties at Rokupr were similar to Gbomsamba. The three-quarter doses which were not significantly different from full doses for the herbicides RiceForce (Pe) and ButaForce (Pe) could be considered for higher marginal returns. The herbicide, Stam (PE) though effective in reducing weed population gave low marginal returns. The results suggest that growing a weed competitive variety and a high yielding variety in conjunction with reduce herbicide rates of RiceForce (Pe) and ButaForce (Pe) could be an effective and economical weed management strategy for rice in the Mangrove Associated Swamp and Boliland ecologies in Sierra Leone.

Key words: Rice varieties; efficacy; herbicide rates; yield; ecologies; MRRs

Abbreviations: MRRs: marginal Rate of Returns; PE: post-emergence; Pe: pre-emergence; CV: coefficient of variation; LSD: least significant difference.

*Corresponding author. E-mail: sokih2003@yahoo.co.uk

1. INTRODUCTION

Continuous rice cropping in the lowlands has resulted in serious weed problems. Weeding by hand is the common practice of controlling weeds. This method is tedious and as such is usually curtailed and inadequately executed resulting in yield reductions (Khan et al., 2003). The use of herbicides have been effective in controlling weeds but because of the high rates normally recommended by manufacturers and cost involved in the purchase of herbicides, farmers hardly apply them.

Effective weed management involves the integration of many practices. Herbicides are undeniably the most effective, reliable technology available today for weed control in rice (Marwat et al., 2004). However, an integrated approach involving the minimal use of chemicals with proper use of other cultural weed control and management techniques such as good land preparation and/or use of weed suppressive varieties will reduce the farmer's dependence on a heavy application of herbicides and thus offers the best hope for increasing food production (Shakoor et al., 2000).

Rice cultivation in the Mangrove Associated Swamps and Bolilands of Sierra Leone is difficult and yields are low due to their topography, soil nutrient status and heavy weed infestation.

The Mangrove Associated Swamps are located on the upper reaches of the Mangrove Swamp catena and grade into the adjacent uplands in which the soil fertility status is low with nitrogen and phosphorus being the major nutrient deficiencies for crop growth. As a result weed infestation is high, posing a major bottleneck for increasing rice productivity whilst the Bolilands are poorly drained saucer-shaped depressions lying on old river basins and normally carry a hard pan making drainage very slow and weed infestation extremely high. Yields in these ecologies ranged from 0.4 - 1 ton ha⁻¹ (MAFFS, 2005).

Studies were therefore carried out at Rokupr in the Mangrove Associated Swamp and at Gbomsamba in the Boliland ecologies to determine (i) the effectiveness of different rates of application of Pre- and post-emergence herbicides on weed growth and yield of rice varieties and (ii) identify suitable herbicides for the two ecologies and (iii) the cost benefit of herbicides application.

2. MATERIALS AND METHODS

Two rice varieties NERICA L19, a weed competitive variety and ROK10 a non-competitive but high yielding variety were subjected to four different herbicides (two pre-and two post-emergence) at four different rates with different active ingredients. The studies were carried out at the Mangrove Associated Swamp at Rokupr and the Boliland at Gbomsamba during the raining season of 2009 and 2010 cropping seasons. The variety ROK10 is the Centre release variety, high yielding but not competitive with weeds, is intermediate in height (125-130 cm) and highly tillered with duration of 170-180 days. The variety NERICA L19 was developed at the West African Rice Development Association (WARDA, 2001) now called Africa Rice centre (ARC). It is high yielding, competitive and is short (85–100 cm) with a duration of 95-105 days.

The herbicide, RiceForce which acts as pre-emergence and post-emergence was taken as two different herbicides with active ingredient oxadiazon at 0.25 kg ha⁻¹ (a). This herbicide was applied at two weeks before transplanting (Pe) and four (4) weeks after transplanting (PE). It is a selective contact herbicide used to control annual grasses, sedges and broadleaf weeds in rice. ButaForce (Pe) with active ingredient butachlor at 0.5 kg ha⁻¹ (a) was applied as pre-emergence four days after transplanting. It is a selective systemic pre-emergence herbicide for the control of annual grasses and certain broadleaf weeds while Stam (PE) with active ingredient propanil at 0.36 kg ha⁻¹ (a) was applied four weeks after transplanting. Four rates of applications (Full dose, Three-quarter dose, Half dose and zero dose (Control)) for each of the herbicides evaluated were obtained from manufacturers' recommended labeled rates of application which are, 5 and 2 l ha⁻¹ for RiceForce and ButaForce, respectively and 18 l ha⁻¹ for Stam (see Table 1 below). The MRRs was computed from series of calculations based on variable cost components which included seeds, fertilizers, herbicides, land preparation, planting, weeding, fertilizer application, herbicide application, harvesting, threshing and bags (sacks). The farm gate price of paddy rice at the time the studies were under taken were Le4000/kg and Le2400/kg for NERICA L19 and ROK10, respectively. These farm gate prices were used in estimating the revenue and comparing with the total variable costs to obtain the gross margin which measured the economic performance of the four herbicides.

Table 1: Active ingredient and Rates of application (l ha⁻¹) obtained from Manufacturers' label.

Herbicide	Active Ingredient	Herbicide rate of Application (l ha ⁻¹)		
		Half dose	Three-quarter dose	Full dose
RiceForce (Pe)	Oxadiazon @ 0.25 kg ha ⁻¹	2.5	3.8	5
ButaForce (Pe)	Butachlor @ 0.5 kg ha ⁻¹	1	1.5	2
RiceForce (PE)	Oxadiazon @ 0.25 kg ha ⁻¹	2.5	3.8	5
Stam (PE)	Propanil @ 0.36 kg ha ⁻¹	9	13.5	18

Two varieties, four herbicides and four rates of application were main factor treatments within a randomized complete block design with three replications. Three weeks old seedlings of the rice varieties were transplanted on the 25th July and 27th July, 2009 and 2010, respectively, in the Mangrove Associated Swamp at Rokupr and on the 6th September and 10th September, 2009 and 2010, respectively, in the Boliland at Gbomsamba into gross plots of 15m² at spacing of 20 cm x 20 cm apart. Fertilization at the rate of 60-40-40 NP₂O₅K₂O in the form NPK 15-15-15 compound fertilizer was broadcast two weeks after transplanting. At 40 days after transplanting 20 kg ha⁻¹ N (nitrogen) was topdressed.

Two sample quadrants of 1m² each were used to collect data on weed count at harvest. 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 weed count. Partial budget and marginal analysis were done to determine the economic cost benefit of herbicide application.

2.1. Description of study site

Two rice ecologies selected for the studies were the Mangrove Associated Swamp and the Boliland. The Mangrove Associated Swamp was at the upper reaches of the main Mangrove Swamp catena and grade into the adjacent uplands. It was 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 soils were predominantly clay (Kaolinite) with a massive structural consistence. Soil reaction was acidic with pH range of 4.5 - 5.5; and was characterized by toxic levels of iron and aluminium. The soil fertility status was low with nitrogen and phosphorus being the major nutrient deficiencies. The Boliland was poorly drained with saucer-shaped depressions lying on old river basins and in addition to high phosphorus adsorption capacity and high acidity; the soils are deficient in nitrogen.

3. RESULTS AND DISCUSSION

Application of herbicides at different rates significantly reduced weed population. Percentage reduction in weed population over control ranged from 65 to as high as 91 percent in 2009 for RiceForce (PE) and Stam (PE), respectively (Table 2). In 2010 percentage weed reductions ranged from 68 to 87 for RiceForce (PE) and ButaForce (Pe), respectively. These ranges in reductions suggest that herbicides differ in their efficacy to control weeds (Table 2). The herbicides RiceForce, ButaForce and Stam with active ingredients oxadiazon, butachlor and propanil, respectively, were effective in controlling weeds. Work done by Adeosun et al. (2009) reported herbicides containing oxadiazon as equally effective as pendimethalin in combating weeds in upland rice in Katsina State of Nigeria. However, with increase in rates of application of herbicides, there were corresponding increases in percent reductions in weed population but these increases were not significantly different for rates of application but were significant for herbicides (Table 2). Similar work done by Khan et al. (1999 and 2003) and by Shakoor et al. (2000) reported weed reductions of over 90 percent in wheat and sorghum, respectively.

Table 2: Effect of herbicide x rates interaction on percentage reduction in weed population over control.

Herbicide	Rate of Application							
	2009				2010			
	½ dose	¾ dose	Full dose	Control	½ dose	¾ dose	Full dose	Control
RiceForce (Pe)	77 79	59 84	57 85	369 -	95 76	66 84	70 83	404 -
ButaForce (Pe)	92 78	61 85	61 85	410 -	100 79	65 86	61 87	473 -
RiceForce (PE)	172 65	157 68	142 71	495 -	190 68	173 71	185 67	590 -
Stam (PE)	60 86	36 91	37 91	418 -	127 79	110 82	100 84	608 -

CV (%) = 8.9 LSD (0.05) = 9.3 CV (%) = 14.1 LSD (0.05) = 10.2
 Numbers in black denote weed population/m²
 Numbers in red denote percentage reduction in weed population over control

All treatments for the different herbicides gave significantly higher grain yields than control plots. Grain yields of plots increased with the increased in treatments from half to full dose in both years (Table 3). The variety NERICA L19 gave similar yields to ROK10 with the application of herbicides (Table 4) except for RiceForce (PE) both in 2009 and 2010.

Table 3: The effect of Herbicide x rate interaction on grain yield (kg ha⁻¹) of rice varieties

Herbicide	Rate of Application							
	2009				2010			
	½ dose	¾ dose	Full dose	Control	½ dose	¾ dose	Full dose	Control
RiceForce (Pe)	2940	3376	3532	1990	2466	3194	3260	1813
ButaForce (Pe)	2642	2760	2996	1538	2518	3200	3210	1511
RiceForce (PE)	1351	1788	1896	1128	1212	1562	1619	987
Stam (PE)	2958	3416	3511	1034	2396	3299	3444	1171

CV (%) = 3.1 LSD (0.05) 240.4 CV (%) = 11.6 LSD (0.05) = 213.6

Table4: The effect of Herbicide x Variety interaction on grain yield of rice varieties

Herbicide	2009		2010	
	Variety		Variety	
	NERICA L19	ROK10	NERICAL19	ROK10
RiceForce (Pe)	2883	3037	2680	2611
ButaForce (Pe)	2262	2480	2354	2467
RiceForce (PE)	1879	1428	1260	994
Stam (PE)	3075	2869	2516	2412

CV (%) = 3.1 LSD (0.05) 240.0 CV (%) = 15.8 LSD (0.05) = 110.7

The interaction effect between rate and variety in both years illustrates that there was no significant difference between varieties for each treatment dose (Table 5). Significant yield differences were observed with increase in treatment dose from half to three-quarter dose. The three-quarter dose was similar to full dose application of the herbicides. However, yields of ROK10 were significantly reduced in control plots (Table 5). This suggests that oxadiazon, butachlor and propanil gave satisfactory performance in terms of weed control and yield of paddy than the control plots. Similar observations have been made by several authors that oxadiazon is effective in controlling weeds and also in increasing yields of rice in direct seeded upland rice (Adeosun et al., 2009; Ikuenobe et al., 2005)

Table5: The effect of Rate x Variety interaction on grain yield of rice varieties

Rate	2009		2010	
	Variety		Variety	
	NERICA L19	ROK10	NERICAL19	ROK10
½ dose	2347	2583	2119	2113
¾ dose	2778	2893	2465	2437
Full dose	2978	2989	2400	2371
Control	1996	1349	1826	1563
CV (%) = 3.1 LSD (0.05) 244.0 CV (%) = 15.8 LSD (0.05) =110.7				

The effectiveness of oxadiazon as pre-emergence, butachlor and propanil in controlling weeds (Table 2) was reflected in the high yields obtained (Tables 3 and 4). High MRRs were also obtained for RiceForce (Pe) with oxadiazon as active ingredient and ButaForce (Pe) with butachlor as active ingredient. However, the MRRs was low (Table 6) for Stam due to its high rate of application (Table1) which affected the gross and net benefits. In 2009, MRRs from no application to three-quarter dose application of RiceForce (Pe) were 1762% and 1955% and for ButaForce (Pe) were 1407% and 1574% for the varieties L19 and ROK10, respectively whilst for Stam (PE) from no application to three-quarter dose application were 75% and 85% and for RiceForce (Pe) were 88% and 96% for NERICA L19 and ROK10, respectively. Similar trend was also observed in 2010 (Table 6).

Table6: Marginal Rate of Returns from Rice Varieties and Herbicides

Herbicide	2009		2010	
	MRRs		MRRs	
	NERICA L19	ROK10	NERICA L19	ROK10
RiceForce (Pe)	1762	1955	1591	1599
ButaForce (Pe)	1407	1574	1248	1326
RiceForce (PE)	88	96	71	76
Stam (PE)	75	85	69	98

4. CONCLUSIONS

Weed population significantly reduced with herbicides application. The herbicides Stam, RiceForce and ButaForce were more effective in reducing weed population in both ecologies. Grain yields of plots treated with herbicides increased with the increased in their rates of application but yields from full and three-quarter doses were similar. Yields of the two varieties at Rokupr were similar to those at Gbomsamba. The three-quarter doses which were similar to full doses could be considered for higher returns. These results suggest that growing weed competitive and high yielding non-competitive varieties in conjunction with reduced herbicide rates of RiceForce and ButaForce as pre-emergence herbicides could be an effective and economical weed management strategy for rice in the Mangrove Associated swamps and Bolilands ecologies in Sierra Leone.

REFERENCES

- Adeosun, J.O., Dauda, C.K., Gezui., Mando, A., Odunze, A.C., Amapu, I.Y., Kudp, T. (2009). On farm weed management in upland rice in three villages of Katsina State of Nigeria. African Crop Science Society. African Crop Science conference proceedings, Vol: 9, 625-629.
- Ikuenobe, C.E., Fadayomi, O., Adeosun, J.O., Gworgwor, N.A., Melifonwu, A.A., Ayeni, A.O. (2005). State of Adoption of improved weed control technologies by farmers in the three agro-ecological Zones of Nigeria. Nigerian Journal of Weed Science 18, 1-19
- Khan, M.A., Zahoor, M., Ahmad, I., Hassan, G., Baloch, M.M.S. (1999). Efficacy of different herbicides for controlling broad leafweeds in wheat (*Tritium aestivum* L.) Pakistan Journal of Biological Sciences (Pakistan) V 2(3), 732-734
- Khan, M.H., Hassan, G., Khan, N., Khan, M.A. (2003). Efficacy of different herbicides for controlling broad leafweeds in wheat (*Tritium aestivum* L.) Pakistan Journal of Biological Sciences (Pakistan) V 2(3), 254-256
- MAFFS, (2005). Ministry of Agriculture Forestry And Food Security. Rice Research Station: Crop Production Guidelines for Sierra Leone. 3-8.
- Marwat, K.B., Khan, I.A., Hassan, G. (2004). Efficacy of different pre-and post-emergence for controlling weeds in chickpea. Pakistan Journal of Weed Science research (Pakistan). V. 10(1-2), 51-54
- Shakoor A., Islam, S., Naeem, M. (2000). Efficacy of different herbicides for control of weeds in sorghum (*Sorghum bicolor* L.) under rainfed conditions. Pakistan Journal of Biological Sciences (Pakistan) V.3 (3), 463-465
- 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 CGIAR King Baudoun Award 2000). ISBN 929113207, 32.