Comparative Performance of Low and High Volume Herbicide Sprays for Weed Control in Lowland Rainfed Rice (*Oryza sativa* L.)

K.P Sibuga*

Sokoine University of Agriculture, Department of Crop Science and Production, P.O. Box 3005, Morogoro. Tanzania.

Abstract

Pre- and post emergence herbicides were evaluated for weed control in lowland rice (Oryza sativa L.)) in field trials during 1998 and 1999 cropping seasons. Herbicides were applied at high volume (416 l/ha) using a knapsack sprayer (CP 15) or at low volume (30 l/ha) using a controlled droplet application (c.d.a.) equipment, the Herbi-4 sprayer. The herbicides tested at varying dosage rates were saturnvalor, Ronstar and Basagran PL 2. In both seasons, Cyperus rotundus L. (purple nutsedge) was the most dominant weed spp. A variety of broadleaf and grass weeds were also observed. All herbicides used stunted the growth of purple nutsedge but none was able to control the weed completely. Hand-weeding was most effective in reducing weed growth and resulted in the highest 2-season average yields in rice (2.7 t/ha). Rice yields were reduced to their lowest levels averaging 1.1 t/ha where no weeding was done. All the herbicide treatments resulted in similar (P>0.05) but relatively lower yields to handweeding in both years. These results suggest that the high volume formulations of Saturnvalor and Basagran PL 2 and Ronstar can be successfully used for weed control in rice using a c.d.a equipment.

Key words: Herbicides, rice, spray volume, weed control.

Introduction

In Tanzania rice, (*Oryza sativa* L.) is the third most important cereal crop (MAC, 1998) after maize *(Zea mays* L.) and millets (*Typhoedium spp*). Rice production in Tanzania is constrained by various pests of which weeds are considered to be the most important (MAC, 1993). Studies on the effects of weeds in rice indicate competition from grasses to be more serious than from broadleaf weeds and sedges combined and that the perennial sedges tend to reduce rice yields more than the annual weeds (De Datta. 1981).

In many parts of Tanzania and East Africa in general, the majority of rice producers practice hand weeding. However, as farm sizes increase, labour for weeding is limited, hence timely removal of weeds becomes impractical. Amongst the weed management options for rice, herbicides are considered most appropriate for cost efficient weed control. This is particularly so where rice seeding is by broadcast or drill method followed by flooding which makes hand weeding difficult (Chang and De Datta. 1974; Subiah and Morachan, 1976 cited by De Datta, 1988).

The equipment most commonly used by small scale farmers in herbicide application is the manually operated knapsack sprayer fitted with a hydraulic pressure nozzle for high volume spraying (300-500 litres per ha). While widely used, such application equipment is not necessarily appropriate as farmers have to fetch and carry large quantities of water. This process is costly, labour intensive and time consuming and may discourage farmers from using herbicides at all and/or at the right time (Matthews. 1990, cited by Clayton. 1992). Controlled droplet application can be implemented with much

*Corresponding author

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less quantities of water and allows treatments to be made much more rapidly and with less effort. Most research data with herbicides in rice and other crops is based on high volume sprays with no comparative performance in low volume (Sibuga *et al*.. 1986: Tarimo. 1994; Mkocha. 1999). This study was formulated with the following objectives in mind:

(i) to evaluate the low volume Herbi-4 sprayer for herbicide application in rice using herbicides formulated for high volume spraying, and

(ii) to evaluate the effectiveness of various pre-and post emergence herbicides for weed control in rice.

Materials and methods

Field experiments were laid out at Sokoine University of Agriculture farm. Morogoro located 6^0S and 30^0 37'E at 525 m.a.s.l. during 1998 and 1999 main rain seasons (February - June). The experimental design for both experiments was a split plot in a randomized complete block replicated three times. The main plots were two spray volumes; high volume (416 l/ha) and low volume (30 l/ha) determined by calibration of a conventional knapsack sprayer (CP 15) and a c.d.a equipment (Micron Herbi-4 sprayer). respectively. Water was used as the diluent. Subplot treatments were pre-emergence herbicides Saturnvalor (a mixture of benthiocarb: (s-4-chlorobenzyl diethylthicarbamate) and prometrin: ($N^2.N^4$-di-isopropyl-6-methylthio-1.3.5-triazine-2. 4-diamine), at 4.4 and 5.5 kg a.i ha^{-1}. respectively. and a post-emergence herbicide Basagran PL 2 (a mixture of bentazon: 3-isopropyl-1H-2.1.3-benzothiadiazin-4-(3H)-one 2,2-dioxide and propanil: 3'.4'-dichloropropionanilide[N-(3.4-dichlorophenyl)propionamide]) at 3.5 and 4.5 kg a.i ha^{-1}. respectively. Ronstar [2-tert-butyl-4-(2,4-dichloro-5-isopropoxyphenyl) -2-1.3.4-oxadiazolin-5-one] at 1.25 kg a.i ha^{-1} was included as a standard herbicide treatment.

The subplot size was 10 x 2 m. with 0.5 m paths between plots and 1.0 m paths between replications. Rice cv. Katrin was direct seeded in bunded plots in rows 20 cm apart. Four to six seeds were sown on hills 20 cm apart on February 21. 1998 and February 28. 1999 and thinned to leave two or three seedlings per hill 10 days after emergence. At the time of sowing. the soils were moist but not flooded yet. Pre-emergence herbicide treatments were applied the following morning after sowing. Post-emergence herbicide treatments were applied 17 days after sowing by which time grasses were in the two-to-three leaf stage and broadleaf weeds in the 4-leaf stage. At this time, the water level in the plots was 3-5 cm deep.

Nitrogen (using sulphate of ammonia. 21% N) at the rate of 120 kg N ha^{-1} was applied in two splits of 60 kg N ha^{-1} at tiller initiation stage and the remaining 60 kg N ha^{-1} applied at panicle initiation stage. Weeds were counted on two randomly placed 0.5 x 0.5 m quadrats. five days after post-emergence herbicide application. Weeding was done twice. first at three weeks after sowing and repeated three weeks later. At the time of harvesting. weeds were cut at ground level and separated into grasses. broadleaf and sedges and oven-dried for 72 hours to determine dry weight. Data on growth and yield variables of rice was also recorded.

Results and discussion

Weed growth and biomass production

The total rainfall received during the cropping season in 1998 was much higher than in 1999 (Figure 1) especially between March and April.

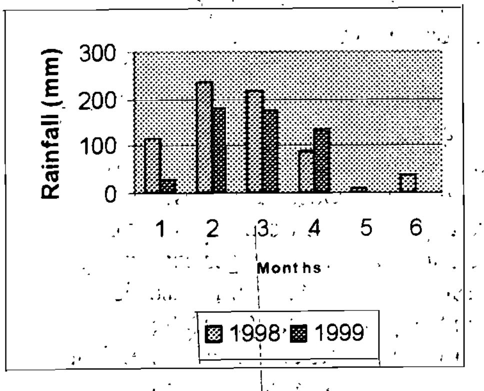

Figure 1: Rainfall received during experimentation period: 1=February ; 2= March; 3= April; 4=May: 5=June; 6=July

The wet soil condition early in the season encouraged early weed emergence particularly *Cyperus rotundus* (purple nutsedges) which was the single dominant species in both seasons (Table 1) regardless of the spray volume. All herbicides stunted the growth of purple nut sedges, but none of the treatments was able to eliminate the weed completely. Observations made in this study could be ascribed to the absence of flood water in the early stages of rice seedling growth. In both seasons, standing water in the plots was first noticed 16 -18 days after sowing in either season. By this time weeds, especially the water-loving purple nutsedge, were well established. Further, the moist conditions encouraged vigorous growth and competitiveness of the nutsedge.

Only two grass species were observed (Table 1). A variety of broadleaf weeds were present of which *Sida alba* and *Gisekia* spp. were the most abundant. Despite the dominance of purple nut sedges, however, broadleaf weeds contributed the highest proportion to the weed biomass. The competitiveness of broadleaf weeds is dependent not only on their abundancy but on their capacity to trap sunlight radiation through the large leaf area and generate biomass rather quickly compared to narrow leaved weed species. Characteristically, broadleaf weeds accumulate dry matter rather fast (Muzik, 1970) compared to grasses or other narrow leaved weeds such as nutsedges. Weed biomass increases at the expense of crop grain yield. This implies that to reduce yield losses, farmers need to pay attention to broadleaf weeds even if present at relatively low density.

Table 1: Weed species observed (in decreasing order of abundance)

	Scientific name	Type
1.	*Cyperus spp(C.rotundus)*: dominant	Sedge
2.	*Sida alba*	Broadleaf
3.	*Echnochloa (colona, crus-gallli)*	Grass
4.	*Gisekia spp*	Broadleaf
5.	*Portulaca oleraceae*	Broadleaf
6.	*Corchorus olitorius*	Broadleaf
7.	*Panicum trichocladum* K.Shum	Grass
8.	*Nicandra physalodes* (L.) Gertn	Broadleaf
9.	*Physalis isorcarpa Hornem*	Broadleaf

The effects of spray volume on weed biomass were not significant ($P > 0.05$) but generally weed biomass production was lower when low volume spays were used except broadleaf weeds(Table 2). Earlier studies have suggested that the phytotoxicity of herbicides could be enhanced when sprayed in low volume. Jordan (1981) reported a six fold increase in the phytotoxicity of glyphosate when the carrier water volume was reduced from 374 l ha^{-1} to 45 l ha^{-1} while Buhler and Burnside (1984) also reported increased phytotoxicity of fluziafop and haloxyfop as carrier water volume

Table 2: Weed dry biosmass for 1998 and 1999 seasons

Treatment	Weed dry weight (gm^2)					
	1998			1999		
	Grasses	B/leaf	Sedges	Grasses	B/leaf	Sedges
Main plot (spray volume)						
Low (30 l/ha)	50.3	183.8	17.3	49.1	134.9	23.2
High (416 l/ha)	52.1	259.5	32.4	74.1	119.9	41.2
Subplot (Weed control treatments)						
1. Ronstar 1.25 kg a.i/ha	28.4*	213.2*	37.2*	86.1*	132.1*	7.8*
2. Basagran PL2 3.5 "	21.7	137.9	33.4	80.0	131.8	42.1
3. Basagran PL2 4.5 "	46.7	249.8	6.6	88.9	129.4	52.5
4. Saturnvalor 4.4 "	7.8	117.3	35.5	47.7	123.1	7.3
5. Saturnvalor 5.5 "	27.6	87.5	43.9	59.7	79.3	32.1
6. Weeded	0.6	23.6	6.6	13.9	24.4	11.4
7. Unweeded	225.5	372.4	50.1	108.0	171.6	73.9

*** Data is mean value for low and high volume for each subplot treatment.**

decreased from 570 to 24 litres ha^{-1}. It can therefore be inferred that the reduced weed dry matter production at the low spray volume was a result of increased herbicide phytotoxicity against weeds, a phenomenon exhibited by the reduced weed growth vigour and consequently dry matter accumulation.

Interestingly, however, is that the apparent increased herbicide phytotoxicity did not lead to any observable injury on the crop. The implication was that the resultant concentrations of herbicide in the low volume sprays were within the range tolerated by the crop. The effect of weed control treatments on weed biomass was similarly non-significant (P>0.05). Compared to the un-weeded plots, weed biomass accumulation amongst the herbicide treated plots was relatively lower though differences were not significant (Table 2). Hence, these results are only indicative of the potential of herbicides in reducing weed growth and possible competition when growing together with rice.

Growth and yield of rice

In the 1998 season, the total number of tillers, number of panicles m^{-2} and grain yield were significantly (P<0.05) influenced by weed control treatments but none of the yield components was significantly (P>0.05) influenced by spray volume or the interaction between spray volume and weed control treatments (Table 3). In the un-weeded plots, the number of tillers and panicles as well as grain yield were reduced significantly (P≤ 0.05) to the lowest levels due to increased competition for growth resources from the weeds. On the other hand, hand-weeding resulted in significantly (P≤ 0.05) highest total number of tillers (199 tillers m^{-2}), number of panicles (158 panicles m^{-2}) and grain yield (3.83 tons ha^{-1}). However, for any one of these variables, differences between hand weeding and any of the herbicide treatments or amongst the herbicide treatments themselves were not significant. Hence, hand weeding or herbicide application were equally effective.

In the 1999 season, only the total number of tillers was significantly (P≤ 0.05) influenced both by spray volume and weed control treatments but not their interaction (Table 4). On the other hand, other variables such as days to 50% flowering and 1000 grain weight were significantly (P <0.05) influenced only by weed control treatments. In this season, total number of tillers was significantly higher for high volume spraying (182 tillers m^{-2}) compared to low volume (150 tillers m^{-2}). This implies that, generally,

Table 3: Growth and yield variables for rice and weed dry weights for different weed control treatments and spray volumes: 1998

Treatment	Days to 50% flowering	Plant height at maturity (cm)	Total number of tillers/m^2	Number of panicles/m^2	Number of filled grains per panicle	Grain yield tons/ha[1]	1000 grain weight (gm)
Main plot (spray vol.)							
High (416 l/ha)	104.1	117.9	149.6	121.2	733.0	2.73	31.5a[2]
Low (30 l/ha)	104.7	79.8	150.7	114.8	803.4	2.91	31.2b
1. Ronstar 1.25kg a.i/ha	105.0*	79.6*	134.0ab*[2]	113.2ab*[2]	967.5*	3.70ab*[2]	29.4*
2. Basagran PL2 3.5kg	104.0	81.5	138.2ab	114.7ab	702.0	3.45ab	33.3
3. Basagran PL2.4 kg	104.0	80.6	169.2ab	124.7ab	622.8	2.72ab	31.3
4. Saturnvalor 4.4kg	104.3	84.4	172.8ab	146.0a	833.8	2.57ab	30.8
5. Saturvalor 5.5kg	106.3	85.0	142.0ab	98.7ab	847.0	2.13ab	31.1
6. Weeded	103.8	84.8	199.3a	158.0a	1021.7	3.83a	31.4
7.Unweeded	103.8	56.1	95.7b	71.0b	400.0	1.33b	31.9
SE ±	1.6	76.8	24.7	22.1	40.1	0.72	1.2
MS CV (%)	2.8	34.6	28.5	32.5	30.7	44.1	6.9

[1]Adjusted to 14% moisture;
[2]Values for main plot or subplot treatments followed by the same letter(s) do not differ significantly according to Duncans Multiple Range Test at 5% level of significance.
***Data is mean value for low and high volume for each subplot treatment.**

spraying at low volume did not significantly alter either the growth pattern of the rice crop and/or the performance of the herbicides despite the higher concentration of the spray mixture in the low volume spray.

The trend for grain yield was similar in both seasons. Hand-weeding was the most effective weed control treatment and grain yields were highest for this treatment in both seasons. Grain filling, indirectly determined by the number of filled grains per panicle, was generally lower in 1999 season compared to the 1998 season. The relatively more efficient grain filling in 1998 partly accounts for the high grain yields in this season.

Table 4: Growth and yield variables for rice and weed dry weights for different weed control treatments and spray volumes: 1999

Treatment	Days to 50% flowring	Plant height at maturity (cm)	Total number of tillers/m^2	Number of panicles/m^2	Number of filled grains per panicle	Grain yield tons/ha[1]	1000 grain weight (gm)
Main plot (spray vol.)=M							
High (416 l/ha)	107.5	39.0	182.0a[2]	104.5	324.5	1.21	28.9
Low (30 l/ha)	107.8	39.8	149.7[b]	87.5	306.5	1.11	28.5
Subplot (Weed control treat.) =S							
1. Ronstar 1.25 kg a.i/ha	110.3a*[2]	37.3*	185.1ab*[2]	111.8*	361.3*	1.24*	28.2ab*[2]
2. Basagran PL2 3.4 "	107.1ab	37.0	199.3ab	61.0	253.5	1.31	28.6ab
3. Basagran PL2 4.5 "	103.3b	41.9	141.6b	80.0	336.0	1.15	28.4ab
4. Saturnvalor 4.4 "	103.3b	42.3	181.0ab	108.1	244.1	1.18	29.3a
5. Saturnvalor 5.5 "	108.0ab	38.2	118.3b	111.1	287.3	0.83	28.3ab
6. Weeded	110.0a	37.0	253.6a	149.3	418.3	1.59	29.1a
7. Unweeded	111.0a	42.1	81.0c	51.1	206.6	0.82	29.1a
SE±	2.1	3.6	24.7	31.8	84.8	0.25	0.4
MS CV (%)	3.4	13.6	27.1	57.4	46.6	37.8	2.1

[1] Adjusted to 14% moisture;

[2] Values, for main plot or subplot treatments followed by the same letter(s) do not differ significantly according to Duncans Multiple Range Test at 5% level of significance.

***Data is mean value for low and high volume for each subplot treatment.**

The crop received much more rainfall in 1998 compared to 1999 particularly during the first two months of growth (Figure 1), which included all the vegetative and early reproductive stages of the crop. Regardless of the season, however, weeding gave the highest yields (3.83 tons ha^{-1} in 1998, and 1.59 tons ha^{-1} in 1999). In the plots which were not weeded throughout the season the crop was overgrown by weeds almost smothering out the rice crop. In these plots weed dry weights increased considerably (Table 2) and rice grain yields were lowest at 1.33 tons ha^{-1} in 1998 (Table 3) and 0.82 tons ha^{-1} in 1999 (Table 4). Grain yields from herbicide treated plots were not significantly (P>0.05) different from the hand weeded plots but in 1998 when crop performance was generally better, Ronstar at 1.25 kg a.i ha^{-1} and Basagran PL 2 at 3.5 kg a.i ha^{-1} were the only herbicide treatments that gave more than 3 tons ha^{-1}. However, the non-significant differences between all the herbicide treatments implies that all the herbicides used were equally effective. The potential of herbicides to reduce weed competition and enhance rice yields has been demonstrated by other researchers (Chang and De Datta. 1974).

Results from other studies on low volume application have varied from no differences in yield between high volume rate and low volume rates (Milton and Strouble. 1972) to better herbicide performance at high volume with herbicides such as paraquat or better performance at low volumes using glyphosate (Merritt and Taylor. 1977). The results reported here indicate no significant differences in performance between high and low volume sprays further reinforcing the unique response of individual herbicides when subjected to different spray volumes. The non-significant differences, for most of the variables recorded, between high and low volume also demonstrated that the current formulations of Ronstar, Basagran PL 2 and saturnvalor, originally intended for high volume spraying with a conventional knapsack sprayer (high volume), could be used for c.d.a using the Micron Herbi-4: a low volume sprayer.

Conclusion

The herbicides used were equally effective against weeds prevalent in the study area. This implies that any of the herbicides tested can be used, the final choice being dictated by relative costs and/or availability. However, the ideal situation would be one where the herbicides are rotated to reduce the possibility of certain weed species developing resistance against any one of them if used continuously over an extended period of time. The non-significant effects of spray volume on most of the variables demonstrated that herbicides such as saturnvalor, Basagran PL 2 and Ronstar, originally formulated for high volume spraying, could be applied in low volume using the use of the Herbi-4 sprayer where available.

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