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Efficacy of Herbicides against Weeds in Transplanted Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To assess the efficacy of different post emergent herbicides against weeds in transplanted rice.
Place and Duration: An experiment was conducted during *Kharif* 2015 and *summer* 2016 at Agricultural Research Station, Dhadesugur, University of Agricultural Sciences, Raichur, Karnataka, India.
Methodology: The experiment comprised of eight treatments and replicated thrice. The complete block design was adopted. The weeds, which were dominant in trials field are *Echinochloa sp. Panicum repens, Cynodon dactylon* and *Leptochloa chinensis* among grasses, *Eclipta alba* and *Ludwigia parviflora* as broad leaf weeds and *Cyperus sp.* as sedge.
Results: All the weed management treatments gave significantly (p=0.05) higher grain yield of rice over weedy check. However, among weed management herbicidal treatments, post emergent application of BAS 9548 H (Penoxsulam 10 g/l + Bentazone 360 g/l SC) @ 3000 ml/ha recorded significantly (p=0.05) higher grain yield followed by the application of BAS 9548 (Penoxsulam 10 g/l + Bentazone 360 g/l SC) @ 2500 ml/ha and twice hand weeding at 15 and 30 days after sowing.

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However, maximum cost benefit ratio was observed in plots treated with BAS 9548 H (Penoxsulam 10 g/l + Bentazone 360 g/l SC) along with twice hand weeded check compared to other herbicide treatments and weedy check in transplanted rice.

Conclusion: Post emergent application (20-22 days after transplanting) of BAS 9548 H (Penoxsulam 10 g/l + Bentazone 360 g/l SC) @ 3000 ml/ha was controlled all types weeds in transplanted rice.

Keywords: Dry weight of weeds; weed control efficiency; BAS 9548 H; grain yield.

1. INTRODUCTION

Rice has been staple food for more than 60 per cent of the world population, providing energy for about 40% of the world population where every third person on earth consumes rice every day in one form or other [1]. Therefore, rice (*Oryza sativa* L.) is an important crop which is extensively grown in tropical and subtropical regions of the world. There are several reasons for its low productivity but the losses due to weeds are one of the most important. More than one third of the total loss (33%) is caused by weeds alone [2]. Weeds are most severe and widespread biological constraints to crop production in India. Weeds are responsible for heavy yield losses in rice, to the extent of complete crop failure under severe infestation conditions. Irrespective of the method of rice establishment, weeds are a major impediment to rice production due to their ability to compete for resources. In general, weeds problem in transplanted rice is lower than that of direct seeded rice because of puddling and stagnation of water in transplanted rice during early growth stage of crop. But in some cases where continuous standing water cannot be maintained particularly for the first 45 days, weed infestation in transplanted rice also may be as high as direct seeded rice. Weeds can reduce the grain yield of dry-seeded rice (DSR) by 75.8%, wet seeded rice (WSR) by 70.6% and transplanted rice (TPR) by 62.6%. Weeds by virtue of their high adaptability and faster growth dominate the crop habitat and reduce the yield potential [3]. Therefore, the present investigation was undertaken to study the effect of early post emergent herbicide for control of major weeds in transplanted rice.

2. MATERIALS AND METHODS

2.1 Background of the Study

A field study was taken during *Kharif*-2015 and *Summer*-2016 on effect of different herbicides against weeds in transplanted rice at Agricultural Research Station, Dhadesugur, University of Agricultural Sciences, Raichur, Karnataka, India. The soil of the experimental site was medium deep black and neutral in pH (8.04), EC (0.47 ds/m), medium in organic carbon content (0.41%), low in nitrogen (189 kg/ha), medium in phosphorus (58.5 kg/ha) and potassium (287.5 kg/ha).

2.2 Treatment Details

There are eight treatments *viz*., **T_1:** BAS 9548 H (Penoxsulam 10 g/l + Bentazone 360 g/l SC) @ 840 g a.i/ha (2270 ml/ha), **T_2:** BAS 9548 H (Penoxsulam 10 g/l + Bentazone 360 g/l SC) @ 925 g a.i/ha (2500 ml/ha), **T_3:** BAS 9548 H (Penoxsulam 10 g/l + Bentazone 360 g/l SC) @ 1110 g a.i/ha (3000 ml/ha), **T_4:** Bentazone 480 g/l SL @ 960 g a.i/ha (2000 ml/ha), **T_5:** Penoxsulam 21.7% SC @ 18 g a.i./ha (83.3 ml/ha), **T_6:** Cyhalofop butyl 10% EC @ 150 g a. i. /ha (1500 ml/ha), **T_7:** Hand weeding and **T_8:** Weedy check.

2.3 Experimental Details

Experiment was laid out with randomized complete block design and replicated thrice with a plot size of 6 m in length and 4 m in width. Twenty five days old seedlings were transplanted at a spacing of 20 cm x 15 cm in August in Kharif 2015 and January in summer 2016. Recommended dose of fertilizer (150:75:75 kg NPK/ha) was applied uniformly in three equal splits (Application of 50% N through urea, 100% P_2O_5 through DAP (Di-ammonium phosphate) and 50% potash through MOP (Muriate of potash) at first split. Application of 25% N through urea and 25% potash through MOP at second split and application of remaining 25% N through urea and 25% potash through MOP at third split). Irrigation comprised of continuous flooding followed by intermittent irrigation at three days interval up to 15 days before harvest. Other agronomic and plant protection measures were adopted as recommended during the crop growth.

2.4 Application of Herbicides and Efficacy Evaluation

Herbicides were sprayed as per the treatments (at 20-22 days after transplanting of crop or at 2-3 leaf stage of weeds) using a Knapsack sprayer fitted with a flat nozzle at a spray volume of 500 l/ha. The efficacy of different treatments on weeds was evaluated at crop maturity. Quadrates (0.25 m^2) were placed in each plot at random to determine the weed density. Weed seedlings within these quadrates were counted and the efficacy of weed control treatments was evaluated by comparing the density with the untreated control. Weeds were cut at ground level, washed with tap water, oven dried at 70℃ for 48 hours and then weighed for dry matter. The weed control efficiency was calculated using the formula as follows [4].

$$\textbf{Weed control efficiency (WCE)} = \frac{\text{Dry weight of weeds under control plot - Dry weight of weeds under treatments}}{\text{Dry weight of weeds under control plot}} \times 100$$

2.5 Data Collection and Economics

After harvest and threshing of crop, grain yield was recorded in net plot wise and converted to grain yield per hectare basis. The cost of inputs that were prevailing at the time of their use was considered for working out the economics of various treatments. Net return per hectare was calculated by deducting the cost of cultivation from gross returns per hectare, gross returns was calculated by using the total income obtained from grain and straw yield of rice and the benefit cost ratio was worked out as follows.

$$\textbf{Benefit cost ratio} = \frac{\text{Gross returns (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

2.6 Succeeding Crop

To see the impact of herbicides on succeeding crop, the black gram crop was sown after harvesting of the rice from the herbicides treated plots and the data recorded on germination of seed and impact on crop growth and development *viz*. Leaf injury on tips and Leaf surface, Wilting, Vein clearing, Necrosis, Epinasty, Hyponasty, stunted growth *etc*. after 7, 15 and 21 days after germination (DAG). The data from in each year analysed separately.

2.7 Data Analysis

MSTAT was used for statistical analysis of data and means were separated using critical difference (CD) at p=0.05. The data on weeds were transformed by square root transformation before being subjected to ANOVA [5].

3. RESULTS AND DISCUSSION

3.1 Effect of Herbicides on Weed Density

3.1.1 Grassy weeds

The grassy weeds which were predominant in trials field are *Echinochloa sp. Panicum repens, Cynodon dactylon* and *Leptochloa chinensis* and presented in Tables 1 and 2. Results revealed that, all the weed management treatments significantly (p=0.05) reduced grassy weeds populations compared to weedy check. Further, post emergence application of BAS 9548 H @ 3000 ml/ha recorded significantly least grassy weeds followed by the application of BAS 9548 H @ 2500 ml/ha and twice hand weeded check as compared to application of Bentazone 480 g/l SL @ 960 g a.i/ha (2000 ml/ha), Penoxsulam 21.7% SC @ 18 g a.i./ha (83.3 ml/ha), Cyhalofop butyl 10% EC @ 150 g a. i. /ha (1500 ml/ha) and weedy check in *Kharif* 2015 and *summer* 2016 when observed at 60 days after transplanting. Post-emergence application of penoxsulam recorded significantly lower grassy weed population in rice [6]. Similarly, penoxsulam as an effective post-emergence herbicide against mixed weed flora in rice [7].

3.1.2 Broad leaf weeds

The predominant broad leaf weeds in the trials field are *Eclipta alba, Commelina communis* and *Ludwigia parviflora.* The data on density of broad leaf weeds recorded in *Kharif* 2015 and *summer* 2016 at 60 days after transplanting are mentioned in Tables 1 and 2. Results revealed that, post emergence application of BAS 9548 H @ 2500 ml/ha was on par with the application of BAS 9548 H @ 3000 ml/ha and twice hand weeded check, found to be significantly superior treatment with recorded lowest population of broad leaf weeds over rest of the treatments. Further, weedy check recorded significantly higher weed population of broad leaf weeds. These results are conformity with the findings of [8].

Table 1. Effect of weed control treatments on weed population (count/m^2), total dry weight and weed control efficiency in transplanted rice at 60 days after transplanting (1st Season- Kharif 2015)

Treatment	Grasses				Broad leaf weeds		*Sedges*	Total weed dry weight (g/m^2)	Weed control efficiency (%)
	Echinichloa sp.	***Panicum repens***	***Cynodon doctylon***	***Leptochloa chinensis***	***Eclipta alba***	***Ludwigia parviflora***	***Cyperus sp.***		
T_1: BAS 9548 H @ 840 g a.i/ha (2270 ml/ha)	1.49 (1.21)	1.40 (0.96)	1.49 (1.21)	1.49 (1.25)	1.46 (1.12)	1.49 (1.21)	1.46 (1.13)	3.98 (14.9)	90.8
T_2: BAS 9548 H @ 925 g a.i/ha (2500 ml/ha)	1.41 (0.98)	1.36 (0.86)	1.41 (0.98)	1.41 (0.98)	1.40 (0.95)	1.41 (0.98)	1.40 (0.95)	3.80 (13.5)	91.6
T_3: BAS 9548 H @ 1110 g a.i/ha (3000 ml/ha)	1.39 (0.92)	1.31 (0.71)	1.40 (0.95)	1.31 (0.71)	1.36 (0.86)	1.36 (0.85)	1.36 (0.86)	3. 53 (11.5)	92.9
T_4: Bentazone 480 g/l SL @ 960 g a.i/ha (2000 ml/ha)	1.66 (1.74)	1.60 (1.56)	1.66 (1.74)	1.66 (1.75)	1.91 (2.65)	1.90 (2.61)	1.67 (1.78)	6.40 (48.0)	70.3
T_5: Penoxulam 21.7% SC @ 18 g a.i./ha (83.3 ml/ha)	1.82 (2.32)	1.81 (2.28)	1.80 (2.25)	1.80 (2.26)	1.81 (2.28)	1.82 (2.31)	1.52 (1.32)	5.99 (40.9)	74.7
T_6: Cyhalofop butyl 10% EC @ 150 g a. i. /ha (1500 ml/ha)	1.54 (1.37)	1.55 (1.39)	1.54 (1.36)	1.54 (1.37)	1.83 (2.35)	1.84 (2.38)	1.57 (1.45)	6.15 (42.9)	73.5
T_7: Hand weeding	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	100
T_8: Weedy check	3.75 (13.1)	3.20 (9.25)	3.52 (11.4)	3.52 (11.8)	3.35 (10.2)	3.33 (10.1)	3.75 (13.1)	12.7 (162)	-
CD at 5%	**0.35**	**0.29**	**0.23**	**0. 18**	**0.25**	**0.21**	**0.41**	**4.05**	**10.8**

Note: Numbers in the parenthesis are original values and numbers in out side the parenthesis are square root transformed values (sq. root of x+1)

Table 2. Effect of weed control treatments on weed population (count/m^2), total dry weight and weed control efficiency in transplanted rice at 60 days after transplanting (2nd Season- Summer 2016)

Treatment	Grasses			Broad leaf weeds			*Sedges*	Total weed dry weight (g/m^2)	Weed control efficiency (%)
	Echinichloa sp.	*Panicum repens*	*Cynodon doctylon*	*Leptochloa chinensis*	*Eclipta alba*	*Ludwigia parviflora*	*Cyperus sp.*		
T_1: BAS 9548 H @ 840 g a.i/ha (2270 ml/ha)	1.50 (1.25)	1.37 (0.90)	1.50 (1.25)	1.49 (1.25)	1.46 (1.12)	1.49 (1.21)	1.46 (1.13)	4.11 (15.9)	91.2
T_2: BAS 9548 H @ 925 g a.i/ha (2500 ml/ha)	1.39 (0.95)	1.36 (0.86)	1.41 (0.98)	1.41 (0.98)	1.40 (0.95)	1.41 (0.98)	1.40 (0.95)	3.67 (12.5)	93.1
T_3: BAS 9548 H @ 1110 g a.i/ha (3000 ml/ha)	1.39 (0.92)	1.31 (0.71)	1.40 (0.95)	1.31 (0.71)	1.36 (0.86)	1.36 (0.85)	1.36 (0.86)	3. 49 (11.2)	93.8
T_4: Bentazone 480 g/l SL @ 960 g a.i/ha (2000 ml/ha)	1.62 (1.64)	1.60 (1.56)	1.66 (1.74)	1.66 (1.75)	1.91 (2.65)	1.90 (2.61)	1.67 (1.78)	6.40 (48.0)	73.6
T_5: Penoxulam 21.7% SC @ 18 g a.i./ha (83.3 ml/ha)	1.82 (2.32)	1.81 (2.28)	1.80 (2.25)	1.80 (2.26)	1.81 (2.28)	1.82 (2.31)	1.52 (1.32)	5.99 (40.9)	77.5
T_6: Cyhalofop butyl 10% EC @ 150 g a. i. /ha (1500 ml/ha)	1.54 (1.37)	1.55 (1.39)	1.54 (1.36)	1.54 (1.37)	1.83 (2.35)	1.84 (2.38)	1.57 (1.45)	6.15 (42.9)	76.4
T_7: Hand weeding	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	100
T_8: Weedy check	3.75 (13.1)	3.20 (9.25)	3.52 (11.4)	3.52 (11.8)	3.35 (10.2)	3.33 (10.1)	3.75 (13.1)	13.5 (182.0)	-
CD at 5%	**0.31**	**0.22**	**0.23**	**0. 19**	**0.25**	**0.21**	**0.42**	**5.05**	**12.9**

Note: Numbers in the parenthesis are original values and figures in out side the parenthesis are square root transformed values (sq. root of x+1)

Table 3. Effect of weed control treatments on yield and economics of transplanted rice (1st Season- Kharif 2015)

Treatment details	Grain yield (kg/ha)	Straw yield (kg/ha)	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	B:C ratio
T_1: BAS 9548 H @ 840 g a.i/ha (2270 ml/ha)	5185	5285	39405	108985	2.77
T_2: BAS 9548 H @ 925 g a.i/ha (2500 ml/ha)	5489	5865	39750	115645	2.91
T_3: BAS 9548 H @ 1110 g a.i/ha (3000 ml/ha)	5787	6051	40500	121791	3.01
T_4: Bentazone 480 g/l SL @ 960 g a.i/ha (2000 ml/ha)	4524	4825	39000	95305	2.44
T_5: Penoxulam 21.7% SC @ 18 g a.i./ha (83.3 ml/ha)	4954	5171	37250	104251	2.80
T_6: Cyhalofop butyl 10% EC @ 150 g a. i. /ha (1500 ml/ha)	4828	5128	38250	101688	2.66
T_7: Hand weeding	6165	6521	43000	129821	3.02
T_8: Weedy check	3541	3818	36000	74638	2.07
C.D. at 5%	**787.0**	**1015**	**5321**	**20885**	**0.26**

3.1.3 Sedges

Generally *Cyperus sp.* are common sedges in rice field. The data on density of sedges recorded at 60 days after transplanting are mentioned in Tables 1 and 2. Results revealed that, post emergence application of BAS 9548 H @ 2500 ml/ha, 3000 ml/ha and twice hand weeded check were found superior over the rest of the treatments in controlling sedge population in transplanted rice. However, post emergence application of Bentazone 480 g/l SL @ 960 g a.i/ha (2000 ml/ha), Penoxsulam 21.7% SC @ 18 g a.i./ha (83.3 ml/ha), Cyhalofop butyl 10% EC @ 150 g a. i. /ha (1500 ml/ha) were onpar with each other in controlling sedge population in transplanted rice. Further, weedy check recorded significantly higher weed population of sedges compared to other weed controlling treatments [9,10].

3.1.4 Effect of herbicides on dry weight of weeds

The data on weed dry weight is presented in Tables 1 and 2. Results revealed that, all the weed management treatments significantly reduced dry weight of weeds as compared to weedy check in *Kharif* 2015 and *Summer* 2016 when observed at 60 days after transplanting. Among the herbicidal treatments, post emergence application of BAS 9548 H @ 2500 ml/ha, 3000 ml/ha and twice hand weeded check, found to be significantly (p=0.05) superior in controlling the weeds and recorded least dry weight of weeds over the rest of the treatments. However, post emergence application of Bentazone 480 g/l SL @ 960 g a.i/ha (2000 ml/ha), Penoxsulam 21.7% SC @ 18 g a.i./ha (83.3 ml/ha), Cyhalofop butyl 10% EC @ 150 g a. i. /ha (1500 ml/ha) were onpar with each other in recording dry weight of weeds by controlling weeds in transplanted rice. Further, weedy check recorded significantly 9p=0.05) higher dry weight of weeds compared to other weed controlling treatments. These results are conformity with the findings of [11,12].

3.1.5 Effect of herbicides on weed control efficiency (WCE)

The data on weed control efficiency in *Kharif* 2015 and *Summer* 2016 is presented in Tables 1 and 2. Results revealed that, post emergence application of BAS 9548 H @ 3000 ml/ha recorded significantly (p=0.05) higher weed control efficiency (92.4 and 92.2% in *Kharif* 2015 and *Summer* 2016, respectively) and which was onpar with the post emergent application of 2500 ml/ha and twice hand weeded check. However, post emergence application of Bentazone 480 g/l SL @ 960 g a.i/ha (2000 ml/ha), Penoxsulam 21.7% SC @ 18 g a.i./ha (83.3 ml/ha), Cyhalofop butyl 10% EC @ 150 g a. i. /ha (1500 ml/ha) were onpar with each other in recording weed control efficiency.

Table 4. Effect of weed control treatments on yield and economics of transplanted rice (2nd Season- Summer 2016)

Treatment details	Grain yield (kg/ha)	Straw yield (kg/ha)	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	B:C ratio
T_1: BAS 9548 H @ 840 g a.i/ha (2270 ml/ha)	5112	5275	39405	107515	2.73
T_2: BAS 9548 H @ 925 g a.i/ha (2500 ml/ha)	5415	5825	39750	114125	2.87
T_3: BAS 9548 H @ 1110 g a.i/ha (3000 ml/ha)	5732	6041	40500	120681	2.98
T_4: Bentazone 480 g/l SL @ 960 g a.i/ha (2000 ml/ha)	4512	4815	39000	95055	2.44
T_5: Penoxulam 21.7% SC @ 18 g a.i./ha (83.3 ml/ha)	4911	5141	37250	103361	2.77
T_6: Cyhalofop butyl 10% EC @ 150 g a. i. /ha (1500 ml/ha)	4802	5118	38250	101158	2.64
T_7: Hand weeding	6112	6501	43000	128741	2.99
T_8: Weedy check	3511	3808	36000	74028	2.06
C.D. at 5%	**728.0**	**925**	**6254**	**22561**	**0.27**

Table 5. Phytotoxicity, growth of black gram as influenced by the application of herbicides (Mean data)

Treatments	Phytotoxic effect (%)			Germination percent
	7 DAG	15 DAG	21 DAG	
T_1: BAS 9548 H @ 840 g a.i/ha (2270 ml/ha)	0.0	0.0	0.0	94.2
T_2: BAS 9548 H @ 925 g a.i/ha (2500 ml/ha)	0.0	0.0	0.0	93.5
T_3: BAS 9548 H @ 1110 g a.i/ha (3000 ml/ha)	0.0	0.0	0.0	93.2
T_4: Bentazone 480 g/l SL @ 960 g a.i/ha (2000 ml/ha)	0.0	0.0	0.0	92.0
T_5: Penoxsulam 21.7% SC @ 18 g a.i./ha (83.3 ml/ha)	0.0	0.0	0.0	96.5
T_6: Cyhalofop butyl 10% EC @ 150 g a. i. /ha (1500 ml/ha)	0.0	0.0	0.0	94.3
T_7: Weedy check (Untreated)	0.0	0.0	0.0	93.6

3.1.6 Effect of herbicides on yield and economics of transplanted rice

In *Kharif* 2015 and *Summer* 2016, all the weed management treatment gave significantly higher grain yield of rice over weedy check. However, among weed management treatments, twice hand weeding at 15 and 30 days after transplanting recorded significantly (p=0.05) higher grain yield (6165 and 6112 kg/ha in *Kharif* 2015 and *Summer* 2016, respectively) and which was onpar with the post emergent application of BAS 9548 H @ 2500 ml/ha (5489 and 5415 kg/ha in *Kharif* 2015 and *Summer* 2016, respectively) and application of BAS 9548 @ 2500 ml/ha (5787 and 5732 kg/ha in *Kharif* 2015 and *Summer* 2016, respectively) compared to other herbicide treatments. However, post emergence application of Bentazone 480 g/l SL @ 960 g a.i/ha (2000 ml/ha), Penoxsulam 21.7% SC @ 18 g a.i./ha (83.3 ml/ha), Cyhalofop butyl 10% EC @ 150 g a. i. /ha (1500 ml/ha) were onpar with each other in recording grain and straw yield. Application of penoxsulam @ 83.3 ml/ha was controlled all types of weeds and increased the grain yield of rice [12]. Moreover, maximum cost benefit ratio was observed in plots treated with BAS 9548 H

along with twice hand weeded check (Tables 3 and 4).

3.1.7 Effect of herbicides on succeeding blackgram crop

The phytotoxicity effect on succeeding blackgram in terms of leaf necrosis, chlorosis or wilting was observed at 7, 15 and 21 days after germination (DAG) at different dosages of BAS 9548 H including other herbicides and untreated control. Results indicated that, there was no phytotoxicity effect (rating 0) noticed in all the plots in both the season. Further there was no impact on germination of black gram seed which was sown after harvesting of rice crop from BAS 9548 H treated plot and other herbicide treated plots including untreated plot in both the season (Table 5).

4. CONCLUSION

Results indicated that, BAS 9548 H (Penoxsulam 10 g/l + Bentazone 360 g/l SC) @ 2500 to 3000 ml/ha could be recommended for post-emergence application at 20-22 days after transplanting to achieve effective control of weeds and to get higher grain yield in transplanted rice.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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