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Efficacy of herbicides and their combination on weed management in transplanted *kharif* rice

K. C. TEJA, B. DUARY AND S. DASH

Institute of Agriculture, Visva-Bharati, Sriniketan-731236, West Bengal

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ABSTRACT

A field experiment was conducted during the kharif season of 2014 and 2015 at the Agricultural Farm, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal with rice variety MTU-7029 to study the effect of sole and combined application of herbicides on weed growth, productivity and economics of transplanted rice. The experiment was laid out in a randomized block design with three replications and eleven treatments. Results revealed that azimsulfuron at 35 g ha^{-1} + 2, 4-D at 500 g ha^{-1} at 25 DAT effectively controlled the grasses, broad-leaved and sedges at 50 DAT which was statistically at par with the pretilachlor at 0.75 kg ha^{-1} + pyrazosulfuron-ethyl at 25 g ha^{-1} at 3 DAT. Weed competition resulted in 33-35% reduction in grain yield. Lower values of weed density and dry weight and higher values of weed control efficiency, herbicide efficiency index, rice grain yield, net return and return per rupee invested were registered with azimsulfuron at 35 g ha^{-1} + 2, 4-D at 500 g ha^{-1} at 25 DAT and was followed by pretilachlor at 0.75 kg ha^{-1} + pyrazosulfuron-ethyl at 25 g ha^{-1} at 3 DAT. These treatments may be recommended in transplanted kharif rice in the lateritic belt of West Bengal.

***Keywords**: Azimsulfuron, herbicide combination, pretilachlor, pyrazosulfuron-ethyl, transplanted rice*

Rice (*Oryza sativa* L.) is the world's most important food crop catering half of the world's population. Cultivation of rice by transplanting in puddled soil is the traditional practice followed in West Bengal. Unlike other cereal crops, rice suffers more from weed competition. About 60% of the weeds emerge during 7-30 days after transplanting (DAT) and strongly compete with rice up to maximum tillering stage (Saha and Rao, 2010). Hence, weed free environment during early crop growth stage should be ensured for higher rice productivity. The loss in grain yield due to unchecked weed growth throughout the crop growth period has been estimated to be 28-45% in transplanted rice (Yadav *et al.*, 2009; Duary, 2014; Duary *et al.,* 2015 b). Hand weeding is commonly followed to control weeds in this crop. However, continuous rain during cropping season, scarcity and high wages of labour, particularly during peak period and early crop-weed competition make this operation difficult and uneconomic. Under such situation, application of herbicide is the only way to manage weeds. The use of herbicide offers selective and economical control of weeds right from the initial stages, giving the crop an advantage of good start and competitive superiority. Application of herbicide may provide effective control of weeds, but continuous use of same herbicide may lead to the evolution of weeds resistant to several herbicides (Duary, 2008). Under such situations mixed or sequential application of herbicides may be useful for broadspectrum weed control in transplanted rice (Duary *et al*., 2015a; Teja *et al.,* 2015). Keeping this in view, a field experiment was carried out to study the effect of herbicides either applied alone or in combination on weed growth, yield and economics of transplanted rice.

MATERIALS AND METHODS

A two year field experiment was conducted during the years 2014 to 2015 at the Agricultural Farm ($23^0$392 N latitude, $87^0$422 E longitude and 58.9 m above the mean sea level), Institute of Agriculture Visva-Bharati, Sriniketan, West Bengal. The soil of the experimental site was sandy loam in texture, acidic in reaction (pH 6.1), low in organic C (0.39%) and available N (142.4 kg ha^{-1}), high in available P (32.13 kg ha^{-1}) and medium in available K (129.77 kg ha^{-1}). The experiment comprised of eleven treatments *viz*., pretilachlor at 0.75 kg ha^{-1} at 3 DAT, pyrazosulfuron-ethyl at 25 g ha^{-1} at 3 DAT, azimsulfuron at 35 g ha^{-1} at 20 DAT, 2,4-D (Na-salt) at 500 g ha^{-1} at 35 DAT, ethoxysulfuron at 15 g ha^{-1} at 20 DAT, fenoxaprop-p-ethyl at 60 g ha^{-1} at 20 DAT, pretilachlor at 0.75 kg ha^{-1} + pyrazosulfuron-ethyl at 25 g ha^{-1} at 3 DAT, azimsulfuron at 35 g ha^{-1} + 2,4-D (Na-salt) at 500 g ha^{-1} at 25 DAT, ethoxysulfuron at 15 g ha^{-1} + fenoxaprop-p-ethyl at 60 g ha^{-1} at 20 DAT, hand weeding twice at 20 and 40 DAT and unweeded control was laid out in randomized block design with three replications. The rice variety '*Swarna'* (MTU-7029) was transplanted with a spacing of 20 × 10 cm during both the years. The recommended dose of fertilizers at 80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1} were applied through urea, DAP, MOP respectively. One third quantity of nitrogen and full amount of phosphorus and potassium were applied in each plot as basal during the final land preparation. Rest two third quantity of N was applied in two splits as top dressing *i.e.*one third of nitrogen was top dressed at active tillering stage and rest one third of nitrogen was top dressed at panicle-initiation. Hand operated knapsack sprayer fitted with

Email: bduary@yahoo.co.in

Table 1: Effect of treatments on density of weeds in transplanted rice at 50 DAT

Treatments	Weed density (No. m^{-2})							
	Grass		Broad leaf		Sedge		Total	
	2014	2015	2014	2015	2014	2015	2014	2015
Pretilachlor at 0.75 kg ha^{-1} at 3 DAT	4.34 (18.33)	4.42 (19.00)	4.71 (21.67)	5.12 (25.67)	3.29 (10.33)	3.24 (10.00)	7.13 (50.33)	7.43 (54.67)
Pyrazosulfuron-ethyl at 25 g ha^{-1} at 3 DAT	4.34 (18.33)	4.30 (18.00)	3.76 (13.67)	4.53 (20.00)	2.61 (6.33)	2.80 (7.33)	6.23 (38.33)	6.79 (45.67)
Azimsulfuron at 35 g ha^{-1} at 20 DAT	2.80 (7.33)	2.48 (5.67)	2.86 (7.67)	2.55 (6.00)	2.35 (5.00)	2.48 (5.67)	4.53 (20.00)	4.22 (17.33)
2,4-D (Na-salt) at 500 g ha^{-1} at 35 DAT	5.40 (28.67)	5.18 (26.33)	4.02 (15.67)	3.76 (13.67)	3.67 (13.00)	3.98 (15.33)	7.60 (57.33)	7.47 (55.33)
Ethoxysulfuron at 15 g ha^{-1} at 20 DAT	4.67 (21.33)	4.45 (19.33)	3.44 (11.33)	3.58 (12.33)	2.55 (6.00)	2.80 (7.33)	6.26 (38.67)	6.28 (39.00)
Fenoxaprop-p-ethyl at 60 g ha^{-1} at 20 DAT	2.04 (3.67)	1.96 (3.33)	5.87 (34.00)	6.67 (44.00)	4.10 (16.33)	4.14 (16.67)	7.38 (54.00)	8.03 (64.00)
Pretilachlor at 0.75 kg ha^{-1} + pyrazosulfuron-ethyl at 25 g ha^{-1} at 3 DAT	2.35 (5.00)	2.42 (5.33)	1.87 (3.00)	1.96 (3.33)	1.47 (1.67)	1.68 (2.33)	3.19 (9.67)	3.39 (11.00)
Azimsulfuron at 35 g ha^{-1} + 2,4-D (Na-salt) at 500 g ha^{-1} at 25 DAT	1.96 (3.33)	1.87 (3.00)	1.47 (1.67)	1.58 (2.00)	1.08 (0.67)	1.47 (1.67)	2.48 (5.67)	2.74 (7.00)
Ethoxysulfuron at 15 g ha^{-1} + fenoxaprop-p-ethyl at 60 g ha^{-1} at 20 DAT	1.68 (2.33)	1.47 (1.67)	2.12 (4.00)	2.35 (5.00)	1.58 (2.00)	1.87 (3.00)	2.97 (8.33)	3.19 (9.67)
Hand weeding twice at 20 and 40 DAT	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)
Unweeded control	5.58 (30.67)	5.31 (27.67)	6.04 (36.00)	6.77 (45.33)	4.26 (17.67)	4.45 (19.33)	9.21 (84.33)	9.64 (92.33)
SEm (±)	**0.11**	**0.15**	**0.14**	**0.13**	**0.16**	**0.15**	**0.25**	**0.23**
LSD (0.05)	**0.32**	**0.43**	**0.41**	**0.39**	**0.48**	**0.45**	**0.74**	**0.67**

Note: Figures in parentheses are the original values. The data was transformed to SQRT (x + 0.5) before analysis.

a flat fan type nozzle was used for spraying the herbicides either alone or in combination with a spray volume of 500 litres ha^{-1}.

All other recommended agronomic practices were followed and plant protection measures were adopted as per need. The density of grasses, sedges and broadleaved weeds were recorded at 50 DAT by placing a quadrat of 50 × 50 cm from the marked sampling area of 1.0 m^2 in each plot. For recording their biomass, weed samples were sun-dried and later oven dried at 70° C until constant weight was attained. The data was subjected to square root transformation to normalize their distribution. Grain yield of rice was recorded at harvest and statistically analyzed at 5% level of significance. Economics were computed using the prevailing market prices for inputs and outputs.

$$\text{WCE} = \frac{\text{Dry weight of weeds in control plot} - \text{Dry weight of weeds in treated plot}}{\text{Dry weight of weeds in control plot}} \times 100$$

The herbicide efficiency index (HEI) was calculated by using the following formula as suggested by Sharma and Gangaiah (2009).

$$\text{HEI} = \frac{\dfrac{\text{Yield from treated plot} - \text{Yield from control plot}}{\text{Yield from control plot}} \times 100}{\dfrac{\text{Dry matter of weeds in treated plot}}{\text{Dry matter of weeds in control}} \times 100}$$

Table 2: Effect of treatments on dry weight of weeds in transplanted rice at 50 DAT

Treatments	Weed dry weight (g m^{-2})							
	Grass		Broad leaf		Sedge		Total	
	2014	2015	2014	2015	2014	2015	2014	2015
Pretilachlor at 0.75 kg ha^{-1} at 3 DAT	4.27 (17.75)	4.24 (17.47)	3.20 (9.73)	3.66 (12.87)	3.13 (9.32)	3.08 (9.01)	6.11 (36.80)	6.31 (39.35)
Pyrazosulfuron-ethyl at 25 g ha^{-1} at 3 DAT	4.01 (15.61)	3.89 (14.65)	2.45 (5.49)	3.13 (9.33)	2.27 (4.67)	2.42 (5.37)	5.13 (25.77)	5.46 (29.34)
Azimsulfuron at 35 g ha^{-1}at 20 DAT	2.52 (5.87)	2.18 (4.26)	2.00 (3.51)	1.73 (2.49)	2.02 (3.57)	2.13 (4.05)	3.67 (12.94)	3.36 (10.79)
2,4-D (Na-salt) at 500 g ha^{-1} at 35 DAT	5.25 (27.10)	4.93 (23.84)	2.79 (7.27)	2.51 (5.80)	3.45 (11.42)	3.74 (13.50)	6.80 (45.79)	6.61 (43.15)
Ethoxysulfuron at 15 g ha^{-1} at 20 DAT	4.31 (18.10)	3.97 (15.24)	2.50 (5.75)	2.45 (5.48)	2.29 (4.75)	2.51 (5.78)	5.39 (28.60)	5.20 (26.50)
Fenoxaprop-p-ethyl at 60 g ha^{-1} at 20 DAT	1.88 (3.05)	1.76 (2.61)	4.20 (17.15)	4.74 (22.01)	4.03 (15.74)	4.08 (16.11)	6.04 (35.94)	6.42 (40.73)
Pretilachlor at 0.75 kg ha^{-1} + pyrazosulfuron-ethyl at 25 g ha^{-1} at 3 DAT	1.95 (3.29)	2.06 (3.74)	1.20 (0.95)	1.19 (0.91)	1.28 (1.14)	1.47 (1.67)	2.43 (5.38)	2.61 (6.32)
Azimsulfuron at 35 g ha^{-1} + 2,4-D (Na-salt) at 500 g ha^{-1} at 25 DAT	1.66 (2.25)	1.60 (2.06)	0.82 (0.18)	0.92 (0.35)	0.96 (0.42)	1.23 (1.01)	1.83 (2.85)	1.98 (3.43)
Ethoxysulfuron at 15 g ha^{-1} + fenoxaprop-p-ethyl at 60 g ha^{-1} at 20 DAT	1.48 (1.69)	1.33 (1.28)	1.24 (1.03)	1.46 (1.62)	1.31 (1.22)	1.49 (1.71)	2.11 (3.94)	2.26 (4.61)
Hand weeding twice at 20 and 40 DAT	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)
Unweeded control	5.54 (30.14)	5.62 (31.09)	4.50 (19.72)	4.94 (23.90)	4.43 (19.12)	4.69 (21.51)	8.34 (68.98)	8.77 (76.50)
SEm (±)	**0.11**	**0.11**	**0.13**	**0.11**	**0.12**	**0.10**	**0.21**	**0.23**
LSD (0.05)	**0.32**	**0.31**	**0.39**	**0.33**	**0.35**	**0.29**	**0.61**	**0.69**

Note: Figures in parentheses are the original values. The data was transformed to SQRT (x + 0.5) before analysis.

Table 3: Effect of treatments on yield and economics of transplanted rice

Treatments	Grain yield (kg ha^{-1})		Net return (Rs. ha^{-1})		Return $rupee^{-1}$ invested		Herbicide efficiency index	
	2014	2015	2014	2015	2014	2015	2014	2015
Pretilachlor at 0.75 kg ha^{-1} at 3 DAT	4238	4332	33867	33918	1.29	1.24	0.42	0.46
Pyrazosulfuron-ethyl at 25 g ha^{-1} at 3 DAT	4232	4350	33619	34008	1.28	1.24	0.60	0.62
Azimsulfuron at 35 g ha^{-1}at 20 DAT	4700	4818	39519	39942	1.47	1.42	1.91	2.64
2,4-D (Na-salt) at 500 g ha^{-1} at 35 DAT	3846	4013	29056	29987	1.14	1.12	0.17	0.25
Ethoxysulfuron at 15 g ha^{-1} at 20 DAT	4260	4416	34134	34974	1.30	1.28	0.56	0.75
Fenoxaprop-p-ethyl at 60 g ha^{-1} at 20 DAT	3835	3882	27999	27402	1.06	0.99	0.21	0.20
Pretilachlor at 0.75kg ha^{-1} + pyrazosulfuron-ethyl at 25 g ha^{-1} at 3 DAT	5092	5154	44758	44473	1.65	1.57	6.04	5.67
Azimsulfuron at 35 g ha^{-1} + 2,4-D (Na-salt) at 500 g ha^{-1} at 25 DAT	5161	5357	45797	47248	1.70	1.68	11.89	11.74
Ethoxysulfuron at 15 g ha^{-1} + fenoxaprop-p-ethyl at 60 g ha^{-1} at 20 DAT	4679	4763	38903	38838	1.43	1.37	6.17	5.92
Hand weeding twice at 20 and 40 DAT	5207	5411	42609	44196	1.38	1.38	-	-
Unweeded control	3461	3510	24471	23864	0.99	0.92	0	0
SEm (±)	**123**	**107**	**1636**	**1453**	**0.06**	**0.05**	**123**	**107**
LSD (0.05)	**363**	**317**	**4825**	**4287**	**0.19**	**0.16**	**-**	**-**

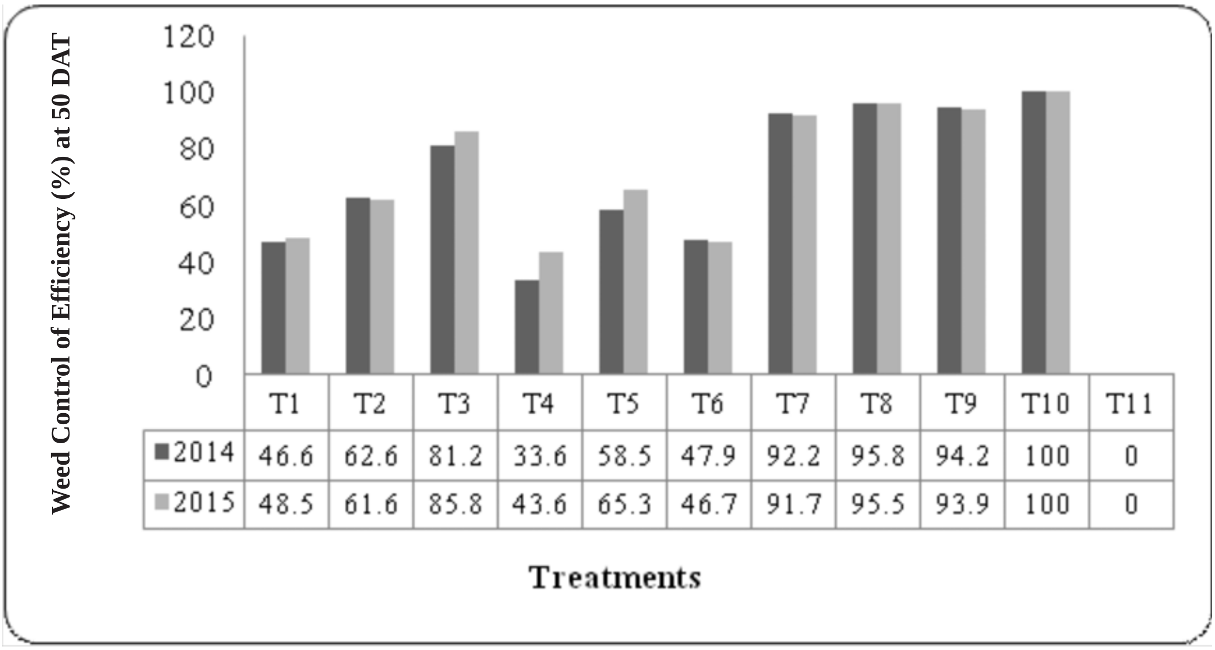

Fig 1: Effect of treatments on Weed control efficiency in transplanted rice at 50 DAT

RESULTS AND DISCUSSION

Eleven weed species belonging to eight different botanical families were present in the experimental field during both the years. *Echinochloa colona* and *Paspalum distichum* among the grasses; *Cyperus iria* among the sedges, and *Ludwigia parviflora* among the broadleaved weeds were predominant throughout the cropping period. Similar weed flora in transplanted rice during *kharif* season has been reported by Duary *et al.* (2015a) and Teja *et al.* (2015).

Results showed that the weed management strategies had a significant effect on density and dry weight of grasses, sedges and broadleaved in both the years of study. As the weeds appeared freely and utilized the resources for a longer period of time the higher density and dry weight of grasses, sedges and broadleaved were recorded in unweeded control as compared to other plots where weeds were controlled by different chemical and physical methods. The lowest density as well as dry weight of grasses, sedges and broadleaved weeds at 50 DAT was recorded with hand weeding twice at 20 and 40 DAT. During both the years, application of ethoxysulfuron at 15 g ha^{-1} + fenoxaprop-p-ethyl at 60 g ha^{-1} at 20 DAT registered the lowest density and dry weight of grasses at 50 DAT which was statistically at par with the combined application of azimsulfuron at 35 g ha^{-1} + 2,4-D at 500 g ha^{-1}. Dewangan and Jatav, (2013) and Duary *et al.* (2015 b) also reported that application of ethoxysulfuron at 15 g ha^{-1} + fenoxaprop-p-ethyl at 60 g ha^{-1} controlled grasses to the extent of 90% compared to weedy check in transplanted rice. Combined application of azimsulfuron at 35 g ha^{-1} + 2, 4-D at 500 g ha^{-1}showed significant suppression of broadleaved weeds and recorded the lowest count and it was closely followed by treatments pretilachlor at 0.75 kg ha^{-1} + pyrazosulfuron-ethyl at 25 g ha^{-1} and ethoxysulfuron at 15 g ha^{-1} + fenoxaprop-p-ethyl at 60 g ha^{-1} at 25 DAT. Similar trend was observed in case of dry weight of broadleaved weeds present in the experimental field at 50 DAT. Among all the herbicidal treatments, application of azimsulfuron at 35 g ha^{-1} + 2,4-D at 500 g ha^{-1} registered the lowest number as well as dry weight of sedges at 50 DAT and was statistically at par with treatments pretilachlor at 0.75 kg ha^{-1} + pyrazosulfuron-ethyl at 25 g ha^{-1} and ethoxysulfuron at 15 g ha^{-1} + fenoxaprop-p-ethyl at 60 g ha^{-1} at 25 DAT. Combined application of azimsulfuron at 35 g ha^{-1} + 2,4-D at 500 g ha^{-1} effectively controlled the complex weed flora present in the experimental field at 50 DAT and recorded the lower number and dry weight of total weeds and which was statistically at par with pretilachlor at 0.75 kg ha^{-1} + pyrazosulfuron-ethyl at 25 g ha^{-1} and ethoxysulfuron at 15 g ha^{-1} + fenoxaprop-p-ethyl at 60 g ha^{-1} at 25 DAT (Table 1, 2). The highest weed control efficiency (WCE) was registered with hand weeding treatment during both years of study (Fig 1). Azimsulfuron at 35 g ha^{-1} + 2, 4-D at 500 g ha^{-1} when applied at 25 DAT resulted higher weed control efficiency at 50 DAT among all the herbicidal treatments and was closely followed by pretilachlor at 0.75 kg ha^{-1} + pyrazosulfuron-ethyl at 25 g ha^{-1}. The higher weed control efficiency with these treatments might be attributed to the lower weed density as well as dry matter accumulation of weeds in these treatments. Duary *et al.* (2015 b) also observed that post-emergence application of azimsulfuron can be used effectively in reducing the weed intensity and dry-matter production by weeds in rice.

Combined application of azimsulfuron @ 35g ha^{-1} + 2, 4-D at 500 g ha^{-1}also registered higher values of herbicide efficiency index during both the years which was closely followed by ethoxysulfuron at 15 g ha^{-1} + fenoxaprop-p-ethyl at 60 g ha^{-1} at 25 DAT and pretilachlor at 0.75 kg ha^{-1} + yrazosulfuron-ethyl at 25 g ha^{-1} at 3 DAT.

Effect on crop

The yield of transplanted rice (Table 3) varied significantly among the treatments. Hand weeding twice at 20 and 40 DAT produced the highest grain yield (5207 and 5411 kg ha^{-1}) during both the years which was at par with combined application of azimsulfuron at 35g ha^{-1} + 2, 4-D at 500 g ha^{-1}(5161 and 5357 kg ha^{-1}) and pretilachlor at 0.75 kg ha^{-1} + pyrazosulfuron-ethyl at 25 g ha^{-1} (5092 and 5154 kg ha^{-1}) during both the years of study. This might be due to effective control of weeds by these treatments providing minimum crop-weed competition throughout the crop growth period, thus enabling the crop for maximum utilization of nutrients, moisture, light and space that accelerated photosynthetic activity ultimately leading to higher grain yield. Weed competition reduced the grain yield to the extent of 33-35% in untreated control plot. Duary (2014), Duary *et al.* (2015 b), Kumar *et al.* (2014), and Teja *et al.* (2015) also reported yield losses to the extent of 29-44% in transplanted rice due to weed competition. Unweeded control registered the lowest grain yield during both years of study.

Economics

The economics of transplanted *kharif* rice indicated that significantly the highest net income (Rs. 45,797 and 47,248 ha^{-1}) and return per rupee invested (1.70 and 1.68) was achieved with application of azimsulfuron at 35 g ha^{-1} + 2, 4-D at 500 g ha^{-1} at 25 DAT closely followed by pretilachlor at 0.75 kg ha^{-1} + pyrazosulfuron-ethyl at 25 g ha^{-1} at 3 DAT (Table 3). This was mainly due to higher economic yield of transplanted rice in these treatments.

From the results of field experiments, combined application of azimsulfuron at 35 g ha^{-1} + 2, 4-D at 500 g ha^{-1} at 25 DAT or pretilachlor at 0.75 kg ha^{-1} + pyrazosulfuron-ethyl at 25 g ha^{-1} at 3 DAT may be recommended for managing complex weed flora and obtaining higher grain yield, net return and return per rupee invested of transplanted *kharif* (wet) rice in the lateritic belt of West Bengal. The recommendation may be passed on to the farmers of rice growing areas in eastern India.

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