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Role of submergence tolerant rice cultivar and herbicides in managing invasive alien weeds

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ABSTRACT

The present investigation was conducted to evolve a suitable weed management practice for invasive alien weeds in transplanted rice at *Annamalai University* Experimental Farm, Annamalainagar, during samba seasons of consecutive years (2015 and 2016). The experiments were laid out in a split plot design with the conventional rice and submergence tolerant rice varieties compared in main plot. Weed management practices, *viz.* unweeded control, twice hand weeding (at 30 and 45 DAT), butachlor 1.5 kg/ha, bensulfuron-methyl 0.06 + pretilachlor 0.6 kg/ha and oxadiargyl 0.07 kg/ha were compared in sub treatments. The results indicated that submergence tolerance as a biological or genetic trait in crops helped suppressing invasive alien weeds like *Leptochloa chinensis* and *Marsilea quadrifolia*, offering biotic resistance to invasion by alien weeds and when integrated with weed control measures. Hence, weed control in submergence tolerant rice with the application of bensulfuron-methyl 0.06 + pretilachlor 0.6 kg/ha could be suggested as an efficient weed control programme for monsoon transplanted rice crop.

INTRODUCTION

Rice cultivation in wetlands are characterised by transplanted mode of cultivation with standing water and crop growing seasons coinciding with monsoon rains. Frequently, excess rainfall during monsoon results in flash floods that lead to complete submergence of the crop. Traditional and popular rice varieties are prone for their susceptibility to complete submergence. Accordingly, submergence tolerant rice varieties are introduced and are being increasingly cultivated as they withstand complete submergence up to ten days. They do not suffer any yield loss compared to conventional varieties (Manzoor *et al.* 2018). Frequent occurrence of flash floods in these rice growing delta regions have resulted in the disappearance of predominant native or naturalised rice weeds like *Echinochloa colona* and *Spenoclea zylanica*, leaving open niches that tend to invite invasion by alien weeds such as *Leptochloa chinensis* and *Marsilea quadrifolia.*

Annamalai University introduced a new submergence tolerant paddy variety "*Sigappi*", developed by incorporating the Sub-1 gene (submergence tolerant gene) in the traditional '*CR 1009*' paddy variety. While retaining the characteristics of the traditional variety, the new one also withstand total submergence for 10 days and yet capable of giving 70 to 80 per cent of the normal yield in 145-150 days (Manzoor *et al.* 2018). This variety is now picking up in Cauvery delta region, the rice granary of Tamil Nadu, which is prone to many natural calamities like uncertain monsoon rains, periodical floods *etc.*

Phytosociological survey of floristic composition of weeds in this region revealed the recent invasion of the wetland rice fields by alien invasive weeds *Leptochloa chinensis* and *Marsilea quadrifolia*. These two weed species dominated over the native weed such as *Echinochloa colona*. and others by virtue of their amphibious adaptation to alternating flooded and residual soil moisture conditions prevalent during recent years in this region (Yaduraju and Kathiresan 2003, Kathiresan 2005, Kathiresan and Gulbert 2016). Alteration in the precipitation and evaporation pattern, more number of wet years annual rainfall excess by ten per cent or more resulting in frequent inundation or flooding resulted in invasion of rice fields of Cauvery river delta in India (Kathiresan 2006, Kathiresan 2009).

Herbicides have become the major weed management tool in rice crop. Hence, the present investigation was conducted to compare the magnitude infestation and competition by invasive alien weeds *Marsilea quadrifolia* and *Leptochloa* *chinensis*, its impact on grain yield of submergence tolerant rice variety and to evaluate weed control by using herbicides in rice prone to complete submergence.

MATERIALS AND METHODS

Field experiments were conducted during *samba (Kharif)* seasons of consecutive years (2015 and 2016) at Annamalai university experimental farm, Department of Agronomy, Annamalainager, Tamil Nadu. The soil was clayey loam with a pH of 7.09. The available nitrogen, phosphorus and potassium content in the soil were 227.4, 19.7 and 342.5 kg/ha respectively. The experiment was laid out in split plot design with three replications. The main plot treatments comprised conventional and submergence tolerant rice varieties namely *BPT* (5204) and *Siggapi* (*CR1009 sub1*). The weed management practices were compared as sub-plots. They included two hand weedings, butachlor 1.5 kg/ha, bensufuron-methyl 0.6 + pretilachlor 6% GR 10 kg/ha and oxadiargyl 0.07 kg/ha. The weed flora was allowed to grow without any disturbance throughout the crop duration in the unweeded control. Hand pulling of weeds was done once at 30 DAT and again at 45 DAT in twice hand weeded plots. In herbicide treatments, the herbicides were sprayed by using knapsack sprayer fitted with flood jet deflector nozzle using 600 L/ha water. Butachlor formulation used was 50% EC 1.25 kg/ha, granular bensulfuron methyl 0.06 + pretilachlor 0.6 kg/ha was mixed with 50 kg sand/ha and they were applied on 4th day after transplanting, oxadiargyl 80% WP was sprayed 0.07kg/ha on 3rd day after transplanting. A thin film of water was maintained at the time of herbicide application.

The crop was manured with 150 kg N, 50 kg P and 50 kg K_2/ha, with half dose of N (75 kg/ha) and full dose of phosphorus (60 kg/ha) and potassium (50 kg/ha) as basal before transplanting. The remaining half nitrogen (75 kg/ha) was top dressed in two equal splits at tillering and panicle initiation stages. Thirty days old seedlings were transplanted in the main field with a spacing of 20x15 cm. The plants were exposed to submergence with water depth of 50 cm after 10 days of transplanting during the field experimentations for seven days and there after normal water depth of 10 cm was maintained.

All other agronomic and plant protection measures were adopted as per the recommended packages. The data on weed density (30 and 60 DAT) and weed dry weight (60 DAT) were recorded with the help of a quadrat of 0.25 m^2. Weed control index of each treatment plot was calculated by using the following formula suggested by Misra and Tosh (1979) and recorded in percentage.

$$\text{WCI} = \frac{a - b}{a} \times 100$$

Where,

a= weed biomass in unweeded control plot

b= weed biomass in treatment plot

Economics of production for the cropping systems were also computed and recorded. The experimental data were statistically analyzed following analysis of variance and least significant difference was worked out at 5% probability level.

RESULTS AND DISCUSSION

Effect on weeds

The weed flora was dominated by *Leptochloa chinensis* and *Marsilea quadrifolia*. Other weeds like *Cyprus rotundus*, *Bergia capensis*, *Eclipta alba*, *Acalypha indica*, and *Echinocloa colona*, were also present but were sporadic in frequency and negligible in occurrence. Among the conventional and submergence tolerant rice varieties tried submergence tolerant rice variety was found to be superior by recording the least population of weeds. This was because of better vegetative growth and canopy coverage during the vegetative phases of the crop growth that suppressed the establishment of *Leptochloa chinensis* and *Marsilea quadrifolia.* The competitive edge is attributable to the physiology of submergence tolerance in the variety *Sigappi* that surpassed the hydrophytic adaptation of the both the invasive alien species. This finding is supported by the earlier reports of Reddy *et al*. (2012).

Weed management practices influenced the weed population greatly. All the weed management treatments resulted in control of weed population. Among the weed control measures compared, the application of bensulfuron-methyl 0.06 + pretilachlor 0.6 kg/ha were significantly superior to the other treatments. Bensulfuron-methyl 0.06 + pretilachlor 0.6 Kg/ha offeredeffective control of annual grasses and broad leaf weeds (*Leptochloa chinensis and Marsilea quadrifolia)* (**Table 1**). This finding is supported by the earlier reports of Anbhazhagan and Kathiresan (2008), Kathiresan and Ramah (2000).

Submergence tolerant rice variety was superior over the conventional variety, in reducing the weed dry matter of 30.0 and 55.2 kg/ha during both seasons. On the other hand, conventional rice varieties encouraged a higher weed dry matter of 60.8 and 70.5 kg/ha during both the seasons. Among the weed control treatments application of bensulfuron-methyl 0.06 + pretilachlor 0.6 kg/ha recorded the least weed dry matter of 10.64 and 15.91 kg/ha during both the seasons. Unweeded control registered the highest weed dry matter of 123.4 and 175.7 kg/ha during both the seasons. The interaction effects between rice varieties and weed management were also significant. The least weed dry matter production was observed with submergence tolerant rice variety along with the application of bensulfuron-methyl 0.06 + pretilachlor 0.6 kg/ha (5.85 kg/ha). Unweeded control in conventional variety recorded the highest dry matter production.

Among the conventional and submergence tolerant rice varieties tried '*Sigappi*' excelled with the highest weed control index of 67.51 and 66.67% during both the seasons. Conventional variety recorded the lowest weed control index of 63.84 and 62.65% during both the seasons. Among the weed control treatments, application of bensulfuron-methyl 0.06 + pretilachlor 0.6 kg/ha recorded the highest weed control index of 94.9 and 91.03% during both the seasons. The interaction effects between rice varieties and weed management were also significant (Gnanavel and Kathiresan 2002) (**Table 2**).

Crop growth, yield attributes and yield

Among the varieties, the submergence tolerant '*Siggappi'* recorded the highest crop dry matter production, panicle/m^2 as compared to conventional variety because of it's ability to overcome the stress due to complete submergence for seven days with 50 cm water column during the period that extended 10 days after transplanting. The conventional variety was not able to recover from the stress and suffered comparative yield reduction, besides the stress from weed competition. All the weed control treatments recorded significantly more number of panicles/ m^2 as compared conventional variety (**Table 3**). Submergence tolerant rice variety exhibited higher yields of 4.09 and 4.54 t /ha during both seasons, respectively. (**Table 3**) This finding is supported by Yamano *et al.* (2013).

Economics of weed control

Economics worked out also favoured the integration of submergence tolerant rice variety with the application of bensulfuron-methyl 0.06 + pretilachlor 0.6 kg/ha, towards achieving a wholistic weed control and profitable production of rice. The highest gross income of ` 1,15,241 and ` 1,17,231 during both seasons, net income of ` 82, 971 and ` 83,510 during both seasons and BCR of ` 2.57 and ` 2.51 during both seasons, (**Table 4**). These are in line with the earlier reports of Reddy *et al.* (2012), Singh *et al.*(1999) and Rachna Sharma and Upadyay (2002).

Table 1. Effect of treatments on individual weed density at 60 days after transplanting

Treatment	*Cyprus rotundus*		*Bergia capensis*		*Eclipta alba*		*Acalypha indica*		*Echinocloa colona*		*Leptochloachinensis*		*Marsilea quadrifolia*	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
BPT (5204)	2.05 (3.73)	1.95 (3.34)	1.90 (3.13)	1.76 (3.1)	1.70 (2.60)	1.12 (1.26)	1.58 (2.00)	1.41 (2.01)	1.64 (2.20)	1.41 (2.01)	5.25 (27.1)	6.54 (42.3)	3.58 (12.3)	3.29 (10.4)
Siggapi	2.37 (5.16)	1.11 (1.25)	1.72 (2.46)	2.04 (3.70)	1.95 (3.33)	1.52 (1.83)	1.62 (2.13)	1.82 (2.83)	1.70 (2.40)	1.82 (2.83)	2.04 (3.7)	3.60 (12.5)	2.85 (7.7)	1.98 (3.4)
LSD (p=0.05)	-	-	-	-	-	-	-	-	-	-	3.21	0.87	0.73	0.44
Unweeded control	2.37 (5.16)	2.06 (4.26)	2.19 (4.33)	1.35 (1.83)	2.30 (4.83)	1.20 (1.46)	2.08 (3.83)	1.44 (2.10)	2.30 (4.83)	1.44 (2.10)	6.83 (46.2)	7.51 (55.9)	1.15 (0.8)	4.12 (16.5)
Twice hand weeding	2.12 (4.00)	1.50 (2.26)	1.52 (1.83)	1.82 (3.33)	1.91 (3.16)	1.22 (1.50)	1.78 (2.67)	1.29 (1.67)	1.87 (3.00)	1.29 (1.67)	4.92 (23.7)	3.07 (8.93)	2.41 (5.3)	1.88 (3.0)
Butachlor 1.25 kg/ha	2.08 (3.83)	1.72 (2.48)	1.47 (1.67)	2.06 (4.25)	1.91 (3.16)	2.08 (4.33)	1.41 (1.50)	1.62 (2.13)	1.35 (1.33)	1.62 (2.13)	1.87 (3.00	6.23 (38.4)	3.02 (8.7)	3.19 (9.7)
Bensulfuron-methyl 0.06 + pretilachlor 0.6 kg/ha	1.95 (3.33)	0.89 (0.89)	1.95 (3.33)	0.91 (0.83)	1.47 (1.67)	0.71 (0.00)	1.35 (1.33)	1.31 (1.73)	1.22 (1.00)	1.31 (1.73)	1.22 (1.0)	2.07 (3.8)	2.97 (8.3)	1.26 (1.1)
Oxadiargyl 0.07 kg/ha	1.82 (2.83)	2.06 (4.26)	1.82 (2.83)	1.82 (2.83)	1.58 (2.00)	1.41 (2.00)	1.22 (1.00)	1.41 (1.50)	1.35 (1.33)	1.41 (1.50)	1.87 (3.0)	5.52 (30.1)	2.48 (5.7)	2.16 (4.2)
LSD (p=0.05)	-	-	-	-	-	-	-	-	-	-	0.65	2.33	0.56	0.58

(Values in parentheses are original values and those outside are square root transformations); - NS

Table 2. Effect of treatments on total weed density, weed dry weight and weed control indexat 60 days after transplanting

Treatment	Weed density (no./m^2)		Weed dry weight (kg/ha)		WCI (%)	
	1stSeason	2ndSeason	1stSeason	2ndSeason	1stSeason	2ndSeason
Main treatment						
BPT (5204)	6.91(47.3)	7.43(54.8)	7.83(60.8)	8.42(70.5)	53.03(63.8)	7.94(62.6)
Siggappi	5.88(34.2)	5.48(29.5)	5.97(30.0)	7.92(55.2)	55.24(67.5)	8.19(66.7)
LSD (p=0.05)	0.65	1.56	0.32	5.5	3.82	1.20
Sub treatment						
Unweeded control	8.93(79.3)	8.97(80.0)	5.31(123.4)	13.75(175.7)	0.70(0)	0.70(0)
Twice hand weeding	6.40(40.5)	4.69(21.5)	7.05(49.8)	5.47(24.8)	65.28(82.5)	9.40(87.9)
Butachlor 1.25 kg/ha	4.69(21.5)	7.45(55.1)	5.40(24.0)	7.16(51.4)	62.85(79.2)	8.93(70.7)
Bensulfuron-methyl 0.06 + pretilachlor 0.6 kg/ha	3.36(10.8)	2.72(6.9)	3.76(10.6)	4.48(15.9)	76.94(94.9)	9.56(91.0)
Oxadiargyl 0.07 kg/ha	4.21(17.2)	6.91(47.3)	5.32(23.3)	7.33(46.7)	59.90(74.9)	8.61(73.6)
LSD (p=0.05)	1.34	3.32	0.45	5.16	5.57	4.20
Interaction						
LSD (p=0.05)	0.14	4.30	0.64	8.17	3.0	5.42
LSD (p=0.05)	2.2	4.70	0.64	7.31	0.25	5.95

Values in parentheses are original values and those outside are square root transformations

Table 3. Effect of treatments on yield parameters at harvest

Treatment	Crop dry matter production at harvest (t/ha)		Panicle/m²		Grain yield (t/ha)		Straw yield (t/ha)	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Main treatment								
BPT (5204)	4.99	7.38	6.23	6.15	2.32	2.88	4.15	4.19
Siggappi	10.99	10.86	6.70	7.19	4.09	4.54	6.12	5.94
LSD (p=0.05)	6.65	0.15	0.50	1.12	2.13	0.70	2.35	0.95
Sub treatment								
Unweeded control	4.03	7.07	4.24	4.84	2.80	2.80	4.60	4.25
Twice hand weeding	10.58	10.46	7.52	7.91	3.51	4.27	5.37	5.65
Butachlor 1.25 kg/ha	6.85	8.61	6.56	6.09	3.00	3.50	5.01	4.96
Bensulfuron-methyl 0.06 + pretilachlor 0.6 kg/ha	11.33	10.35	7.26	7.86	3.58	4.26	5.55	5.53
Oxadiargyl 0.07 kg/ha	7.16	9.11	6.30	6.67	3.10	3.73	5.15	5.18
LSD (p=0.05)	2.17	0.53	0.30	0.27	0.08	0.12	0.5	0.18
Interaction								
LSD (p=0.05)	5.90	0.69	2.91	1.13	1.40	0.70	1.57	0.95
LSD (p=0.05)	2.68	0.76	2.50	0.38	0.04	0.18	0.50	0.26

Table 4. Effect of treatments on economics

Treatment	Cost of cultivation (x10³ `/ha)		Gross income (x10³ `/ha)		Net income (x10³ `/ha)		Benefit cost ratio	
	1st Season	2st Season	1st Season	2st Season	1st Season	2st Season	1st Season	2st Season
BPT (5204)								
Unweeded control	32.00	32.12	57.75	59.05	25.75	26.93	0.80	0.83
Twice hand weeding	34.43	34.52	75.30	83.05	40.87	48.53	1.18	1.40
Butachlor 1.25 kg/ha	32.44	32.59	61.30	65.29	28.86	32.70	0.88	1.00
Bensulfuron-methyl 0.06 + pretilachlor 0.6 kg/ha	32.15	34.01	74.00	82.19	41.86	48.82	1.30	1.46
Oxadiargyl 0.07 kg/ha	32.63	33.05	66.00	78.39	33.37	45.34	1.02	1.37
Siggapi								
Unweeded control	31.20	32.70	72.43	73.47	41.23	40.77	1.32	1.24
Twice hand weeding	33.16	33.72	115.29	117.23	82.13	83.51	2.47	2.48
Butachlor 1.25 kg/ha	34.25	34.27	77.69	117.29	83.44	83.02	2.43	2.42
Bensulfuron-methyl 0.06 + pretilachlor 0.6 kg/ha	32.27	33.72	115.24	118.45	82.97	84.73	2.57	2.51
Oxadiargyl 0.07 kg/ha	32.05	35.31	109.45	119.67	77.40	84.36	2.41	2.38

The results indicated that submergence tolerance as a biological or genetic trait in crops helped suppressing invasive alien weeds like *Leptochloa chinensis* and *Marsileaquadrifolia*, offering biotic resistance to invasion by alien weeds and when integrated with weed control measures were efficient in suppressing these alien weeds.

Hence, weed control using submergence tolerant rice along with the application of bensulfuron-methyl 0.06 + pretilachlor 0.6 kg/ha could be suggested as an efficient weed control programme, for monsoon transplanted rice crop.

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