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Weed dynamics and production potential of direct-seeded rice cultivars as influenced by weed management

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ABSTRACT

The field study was undertaken during rainy season of 2012 and 2013 to evaluate the rice cultivars and weed management effects on weeds growth and yield of direct-seeded rice (DSR) cultivars. The associated weed flora include *Echinochloa colona*, *Echinocloa crus-galli*, *Cynodon dactylon* as grasses; *Cyperus rotundus*, *Cyperus iria* as sedges; *Caesulia auxillaries* and *Eclipta alba* as broad-leaved weeds. Bispyribac-sodium + azimsulfuron (25 + 35 g/ha) + 0.25% NIS as post-emergence at 15-20 DAS was found to be most effective in minimizing weed density, biomass and in enhancing the weed control efficiency 40.9% and 38.0% during 2012 and 2013 at 60 DAS, respectively. The maximum rice grain, straw and biological yield was found with application of bispyribac + azimsulfuron (25 g + 35 g/ha) + 0.25% NIS as post-emergence at 15-20 DAS and was significantly superior over rest of the treatments during both the years of study.

Key words: Direct-seeded rice, Rice cultivars, Weed control, Zero-tillage

Dry direct-seeding (DSR) is probably the oldest method of crop establishment. Historical accounts of rice cultivation in Asia indicate that, during its early period of domestication, rice used to be dry sown in a mixture with other crops that were established under the shifting cultivation system (Grigg 1974). In 21th century, scarcity of agricultural land and water and continuing shortage of labour would encourage a shift towards direct-seeding method of rice production system (Mortimer *et al*. 2005). Despite several advantages (Balasubranmanian and Hill 2002) of DSR, various production obstacles are also encountered in direct-seeded rice, of which heavy weed infestation is the major one. Weeds cause heavy damage to DSR crop, which can be to the tune of 5-100% (Rao *et al*. 2007). Manual removal of weeds is labour intensive, tedious, back breaking and does not ensure weed removal at critical stage of crop-weed competition due to non-availability of labours and sometimes bad weather condition, which does not allow labours to move in the field. Thus, herbicides are considered to be an alternatives to hand weeding (Singh *et al*. 2007). Herbicides are more effective in controlling the weeds besides reducing the total energy requirement for rice cultivation. Besides chemicals and manual weeding, agronomic practices like crop establishment by zero tillage or reduced tillage with residue retention play an important role in weed suppression and improving the yield. The present study was undertaken to study the effect of different rice cultivars and weed management practices on weeds, rice growth and yield in direct dry-seeded rice.

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MATERIALS AND METHODS

The field experiment was undertaken for two years during *Kharif* (rainy season) 2012 and 2013 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India (25°18' N latitude, 83°03' E longitude and at an altitude of 75.7 m above mean sea level) in the Northern-Gangetic alluvial plains having characteristics of sub-tropical climate. The soil of the experimental site was sandy clay loam in texture with pH 7.2. It was moderately fertile, being low in organic carbon (0.43%), available nitrogen (198 kg/ha) and medium in available phosphorus (24.6 kg/ha) and potassium (210 kg/ha). The crops received 622.2 mm of rainfall during 2012 and 818.3 mm in 2013. The rainfall observed to be higher in initial stage but later it was uniformly distributed throughout the crop period during the second year. The weekly mean maximum temperature varied from 28.4 to 40.8 °C (average 32.36 °C) and 26.7 to 35.5 °C (average 31.41 °C) along with minimum temperature ranged from 15.3 to 29.5 °C (average 24.42 °C) and 17.3 to 28.3 °C (average of 25.03 °C) during 2012 and 2013, respectively. The weekly mean sun-shine hours in 2012 was low (5.43 h) as compared to 2013 (5.72 h). The weekly mean rate of evaporation was less in second year (3.51 mm) over first year (3.72 mm), respectively.

The experiment was laid out in split-plot design replicated thrice. The treatments comprised four rice cultivars, *viz*. '*Sarjoo-52', 'HUR-105', 'PAU-201'* and '*Arize- 6129'* were assigned to main plots and each main plot were further divided into six sub-plots to accommodate weed management treatments *i.e*. weedy check, weed free, pendimethalin 1.0 kg/ha as pre-emergence (PE), pendimethalin 1.0 kg/ha *fb* bispyribac-sodium 25 g/ha + 0.25% NIS as post emergence (PoE), oxadiargyl 90 g/ha *fb* bispyribac-sodium 25 g/ha + 0.25% NIS (PoE), bispyribac-sodium + azimsulfuron (25 + 35 g/ha) + 0.25% NIS (PoE). Seeding of all the cultivars were done with pre-sowing irrigation by zero-till drill machines. An uniform dose of 120 kg N + 60 kg P_2O_5 + 60 kg K_2O + 25 kg $ZnSO_4$/ha was applied in all the treatments in the form of urea, DAP, MOP and $ZnSO_4$, respectively. Half dose of total N and full dose of P_2O_5, K_2O and $ZnSO_4$ was applied as basal and remaining half dose of N was top dressed in two equal instalments at active tillering and panicle initiation stage. Seed rate of 30 kg/ha was used for seeding by zero-till drill machine. Pre-emergence (just after sowing) and post-emergence (as per treatments) herbicides were applied with the help of a hand-operated knapsack sprayer fitted with flat-fan nozzle using water 600 L/ha.

Data on weed density were subjected to square root transformation ($\sqrt{x+0.5}$) before statistical analysis to normalize their distribution. The data were analyzed statistically using method described by Panse and Sukhatme (1978). Data on weeds biomass was recorded by cutting weeds at ground level, washing with tap water, sun followed by oven drying at 70±2 °C for 48 hours and then weighing. To determine the effect of crop growth, data on initial plant population/m row at 20 DAS, plant height (cm), tillers (m/row), plant dry matter (g/m row) were recorded at harvest and leaf area index was recorded at 90 days after sowing. Weed control efficiency was calculated using following formula.

$$WCE = \frac{WDc - WDt}{WDc} \times 100$$

Where, WD_C is the weed density (number/m^2) in control plot; WD_T is the weed density (number/m^2) in treated plot; in both WD_C and WD_T; the unit should be same or uniform.

RESULTS AND DISCUSSION

Experimental field was infested with grasses (*Echinocloa colonum*, *E. Crusgalli*, and *Cynodon dactylon*), sedges (*Cyperus rotundus* and C*yperus iria*) and broad-leaf weeds (*Caexulia auxillaries* and *Eclipta alba*). Among the weed flora, averaged over two years, the maximum relative percentage of weed was grasses, sedges and broad-leaved weeds in all the cultivars.

Effect on weed density

The rice cultivar "*Arize-6129*" had minimum density of weeds among all the cultivars at 60 DAS. Maximum weed density was recorded under '*PAU-201'* (**Table 1**). All weed management practices resulted in significant reduction in total weed density as compared to weedy check. Application of bispyribac-sodium + azimsulfuron (25 + 35 g/ha) + 0.25% NIS PoE at 15-20 DAS showed maximum efficacy in minimizing all kinds of weed flora and proved significantly superior over all the weed management treatments. The next best treatment in this respect was pendimethalin at 1.0 kg/ha (PE) *fb* bispyribac-sodium at 25 g/ha + 0.25% NIS (PoE) at 15-20 DAS. Applications of pendimethalin at 1.0 kg/ha (PE) was less effective as compared to other weed control treatments in minimizing the density of weeds as the field was infected with complex weed flora and this herbicide could not control the flush of weeds of all three types of weeds like, grasses, sedges and broad-leaved weeds at later stage. Singh *et al*. (1999) and Yaduraju and Mishra (2004) also reported that control of initial weed emergence facilitates better environment for direct-seeded rice crop.

Effect on weed biomass and weed control efficiency

Significant variation in total weed biomass under different weed management and crop cultivars was observed. '*Arize-6129*' had minimum weed biomass and the maximum weed biomass was recorded '*PAU-201'* (**Table 1**) due to smothering effect of '*Arize-6129*'. Hussain and Gogoi (1997) also observed significantly lower weed biomass in association with the traditional variety (*Kalaguni*) than in '*IR–36'* variety due to the higher smothering effect of the traditional variety. Among weed management treatments, bispyribac-sodium + azimsulfuron (25 + 35 g/ha) + 0.25% NIS (PoE) recorded the minimum weed dry matter followed by pendimethalin at 1.0 kg/ha (PE) *fb* bispyribac-sodium at 25 g/ha + 0.25% NIS (PoE). This integration of pre- and post-emergence herbicides minimized the weed biomass. Wallia *et al*. (2008) reported effective weed control with integration of pre-emergence application of pendimethalin with post-emergence application of azimsulfuron. The maximum weed biomass was recorded in weedy plots. Among herbicidal treatments, pendimethalin at 1.0 kg/ha (PE) recorded maximum weed biomass.

Weed control efficiency (WCE) of different weed control treatments varied significantly during both the *Kharif* seasons of 2012 and 2013 at 60 days after sowing (**Table 1**). Minimum WCE was recorded in '*PAU-201*' cultivar while maximum in '*Arize-6129*'. Maximum weed control efficiency (100 %) was found with weed free at 60 days after sowing and with bispyribac-sodium + azimsulfuron (25 + 35 g/ha) + 0.25% NIS. The sequential and post-emergence application of herbicide controlled all grassy, sedges and broad-leaved weeds more efficiently and minimized the weed problem. Application of pendimethalin alone was not that effective. The integrated weed control appeared essential for successful direct-seeded rice (Gill 2008).

Effect on crop growth and yield

Application of pre- and post-emergence herbicides did not cause any phytotoxic symptoms on rice plant. Initial plant population was maximum in '*Arize-6129*', which was significantly superior over rest of the crop cultivars (**Table 2**). This was due to cultivar initial weed suppress efficiency of '*Arize-6129*'. Among the weed management methods, maximum initial plant population was recorded with bispyribac-sodium + azimsulfuron + NIS. '*Arize-6129*' plant height at harvest was maximum and was at par with '*Sarjoo-52*'. Among the weed management methods, bispyribac-sodium + azimsulfuron + NIS recorded maximum plant height while at par with pendimethalin *fb* bispyribac-sodium + NIS treatments in both the year. During first and second year, effective tillers were higher in '*Arize-6129*' and were significantly superior over rest of the cultivars. '*Arize-6129*' had recorded maximum plant biomass at harvest (g/m row) and was at par with '*Sarjoo-52*'. '*HUR-105*' was significantly superior over '*PAU-201*'. Similar results were reported earlier (Hussain and Gogoi 1997).

Leaf area index of direct-seeded rice increased with crop age and recorded at 60 days after sowing (**Table 2**). Among the crop cultivars, '*Arize-6129*' had maximum leaf area index than other three cultivars during both the year. In weed management methods, maximum LAI were recorded under weed free treatment and next best treatment recorded with the application of bispyribac-sodium + azimsulfuron

Table 1. Effect of rice cultivars and weed management on weed density, weed biomass and WCE at 60 DAS

Treatment	Weed density (no./m^2)						Weed biomass (g/m^2)		Weed control efficiency (%)	
	Grasses		Sedges		Broad-leaf weeds					
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Rice cultivars										
Sarjoo-52	16.4*	17.3	9.2	9.7	7.4	7.8	8.6	9.1	43.2	41.4
	(322.0)	(357.9)	(99.6)	(110.7)	(64.7)	(71.9)	(87.5)	(97.3)		
HUR-105	17.4	18.2	9.7	10.2	7.9	8.2	9.1	9.6	36.6	35.2
	(359.5)	(395.4)	(111.2)	(122.3)	(72.2)	(79.4)	(97.7)	(107.5)		
PAU-201	18.6	19.4	10.4	10.8	8.4	8.8	9.7	10.2	27.6	26.8
	(410.8)	(446.7)	(127.1)	(138.2)	(82.5)	(89.8)	(111.7)	(121.4)		
Arize-6129	15.3	16.3	8.6	9.1	7.0	7.4	8.1	8.6	50.3	47.9
	(282.0)	(317.8)	(87.2)	(98.3)	(56.7)	(63.9)	(76.7)	(86.4)		
LSD (p=0.05)	0.22	0.24	0.12	0.13	0.10	0.11	0.12	0.12	-	-
Weed management										
Pendimethalin 1.0 kg/ha (PE)	20.1	21.1	11.2	11.8	9.0	9.5	10.5	11.0	28.7	26.6
	(404.6)	(447.7)	(125.2)	(138.5)	(81.3)	(90.0)	(110.0)	(121.7)		
Pendimethalin 1.0 kg/ha (PE) *fb*	19.2	20.3	10.7	11.3	8.6	9.1	10.0	10.6	34.8	32.4
bispyribac-Na 25 g/ha + 0.25% NIS (PoE)	(369.6)	(412.6)	(114.4)	(127.7)	(74.3)	(82.9)	(100.5)	(112.2)		
Oxadiargyl 90 g/ha (PE) *fb* bispyribac-	19.6	20.6	10.9	11.5	8.8	9.3	10.2	10.8	32.2	29.9
Na 25 g/ha + 0.25% NIS (PoE)	(384.6)	(427.6)	(119.0)	(132.3)	(77.3)	(85.9)	(104.6)	(116.3)		
Bispyribac-Na + azimsulfuron (25 + 35	18.3	19.4	10.2	10.8	8.2	8.7	9.5	10.1	40.9	38.0
g/ha) + 0.25% NIS (PoE) 15-20 DAS	(335.4)	(378.5)	(103.8)	(117.1)	(67.4)	(76.0)	(91.2)	(102.9)		
Weedy check	23.8	24.7	13.2	13.7	10.7	11.1	12.4	12.9	0.0	0.0
	(567.2)	(610.2)	(175.5)	(188.8)	(114.0)	(122.6)	(154.2)	(165.9)		
Weed free	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	100.0	100.0
	(0.00)	(0.00)	(0.00)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)		
LSD (p=0.05)	0.34	0.36	0.19	0.20	0.15	0.16	0.18	0.19	-	-

*Data were subjected to square root transformation ($\sqrt{x+0.5}$). Data given in parentheses are original value. DAS- Days after sowing, *fb*- Followed by, PE-Pre-emergence, PoE- Post emergence

Table 2. Effect of rice cultivars and weed management on growth attributes of direct-seeded rice

Treatment	Initial plant population (m/row at 20 DAS)		Plant height (cm)		Tillers (m/row)		Plant biomass (g/m row)		Leaf area index (at 90 DAS)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Rice cultivars										
Sarjoo-52	26.8	23.2	96.1	93.0	60.0	59.0	98.9	97.6	3.94	3.57
HUR-105	24.6	21.8	93.4	90.6	57.3	56.2	98.1	96.8	3.84	3.49
PAU-201	23.8	21.1	89.3	86.5	53.2	52.1	93.4	92.2	3.57	3.26
Arize-6129	28.0	24.8	102.7	99.8	65.3	64.2	100.1	99.1	4.05	3.66
LSD (p=0.05)	2.37	2.16	4.04	4.50	6.12	5.8	3.84	3.44	0.19	0.16
Weed management										
Pendimethalin 1.0 kg/ha (PE)	26.4	23.3	93.7	90.9	57.6	56.5	92.6	91.4	3.75	3.41
Pendimethalin 1.0 kg/ha (PE) *fb* bispyribac-Na 25 g/ha + 0.25% NIS (PoE)	27.5	24.6	97.2	94.4	61.0	59.9	107.4	105.9	3.95	3.58
Oxadiargyl at 90 g/ha (PE) *fb* bispyribac-Na 25 g/ha + 0.25% NIS (PoE)	25.0	22.3	94.2	91.4	58.1	57.0	93.8	92.5	3.84	3.48
Bispyribac-Na + azimsulfuron (25 +35 g/ha) + 0.25% NIS (PoE) 15-20 DAS	28.3	25.0	99.9	97.1	63.7	62.6	113.5	111.9	4.07	3.68
Weedy check	18.2	15.6	83.2	80.1	46.1	45.1	60.4	60.5	2.82	2.64
Weed free	29.4	25.8	104.0	101.1	67.1	66.0	118.1	116.3	4.68	4.18
LSD (p=0.05)	1.09	0.90	3.03	2.98	2.93	2.68	2.34	2.19	0.14	0.12

DAS- Days after sowing, *fb*- Followed by, PE-Pre-emergence, PoE- Post-emergence

Table 3. Effect of rice cultivars and weed management on rice grain, straw and biological yield

Treatment	Grain yield (t/ha)		Straw yield (t/ha)		Biological yield (t/ha)	
	2012	2013	2012	2013	2012	2013
Rice cultivars						
Sarjoo-52	4.10	3.92	6.32	6.16	10.42	10.09
HUR-105	3.91	3.76	6.01	5.86	9.92	9.62
PAU-201	3.42	3.27	5.24	5.11	8.66	8.39
Arize-6129	4.29	4.12	6.56	6.40	10.85	10.52
LSD (p=0.05)	0.35	0.30	0.73	0.65	1.06	0.63
Weed management						
Pendimethalin 1.0 kg/ha (PE)	3.74	3.59	5.93	5.78	9.67	9.37
Pendimethalin 1.0 kg/ha (PE) *fb* bispyribac-Na at 25 g/ha + 0.25% NIS (PoE)	4.11	3.94	6.57	6.40	10.68	10.35
Oxadiargyl 90 g/ha (PE) *fb* bispyribac-Na 25 g/ha + 0.25% NIS (PoE)	3.91	3.74	6.21	6.05	10.12	9.79
Bispyribac-Na + azimsulfuron (25 +35 g/ha) + 0.25% NIS (PoE) 15-20 DAS	4.33	4.16	6.95	6.77	11.28	10.93
Weedy check	2.05	1.96	3.03	2.96	5.08	4.92
Weed free	5.44	5.23	7.52	7.33	12.96	12.56
LSD (p=0.05)	0.25	0.23	0.52	0.50	0.70	0.53

DAS - Days after sowing, *fb* - Followed by

+ NIS during both the years. These results were in agreement with Gill (2008).

The maximum rice grain yield was recorded in '*Arize-6129*' (4.29 t/ha and 4.12 t/ha in 2012 and 2013, respectively) during both the years (**Table 3**). All the herbicidal treatments either applied in sequential combination with herbicides or as sole application, significantly increased yield of rice as compared to weedy check during both the years of study. Among weed management methods, bispyribac-Na + azimsulfuron + NIS (4.33 t/ha and 4.16 t/ha) produced significantly maximum rice grain yield than rest of the treatments during both the years. Kamboj *et al.* (2012) also reported significantly higher grain yield and straw yield with sequential herbicide application as it reduced the weed competition and enabled the direct-seeded rice to better utilize nutrient and growth factors. This can be further explained in terms of negative correlation between total weed biomass and rice grain yield (r^2 = 0.834 and r^2 = 0.809 during 2012 and 2013, respectively) (**Figure 1**). Same trends were also observed in respect of straw and biological yield during both the year of studies.

It was concluded that post-emergence application of herbicides mixture is better than pre- or post-emergence application of single herbicide. Application of bispyribac-sodium + azimsulfuron (25

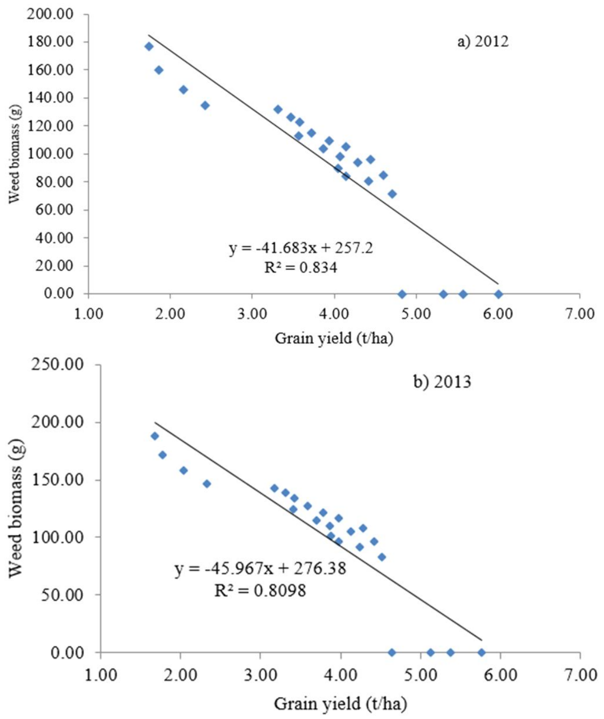

Figure 1. Relationship between weed biomass and rice yield in 2012 (a) and in 2013 (b)

+ 35 g/ha) + 0.25% NIS as PoE at 15-20 DAS was most effective for suppressing weed and improving growth and yield of direct-seeded rice hybrid Arize-6129.

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