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Research Paper

Response of rice (*Oryza sativa*) genotypes to weed management in rainfed ecosystems of eastern India

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ABSTRACT

An experiment was conducted during the rainy seasons of 2013 and 2014 at Patna, Bihar, to study performance of 9 rice (*Oryza sativa* L.) genotypes ('Sahbhagi Dhan', 'Sushk Samrat', 'CR Dhan 40', 'Abhishek', 'IR 84899-B-183-CRA-19-1', 'IR 83387-B-B-40-1', 'IR 82870-11', 'IR 83387-B-B-27-4' and 'IR 83376-B-B-24-2') under 2 weed-management levels [pendimethalin 1.0 kg/ha followed by (*fb*) bispyribac-sodium 30 g/ha at 20 days after sowing (DAS) and 2 hand-weedings at 45 and 65 DAS–low weed pressure; and pendimethalin 1.0 kg/ha alone–medium weed pressure] in the rainfed ecosystem of eastern India. The field was infested mainly with barnyard grass [*Echinochloa colona* L. (Link)], horse purselane (*Trianthema portulacastrum* L.), native gooseberry (*Physalis minia)*, purple nutsedge *(Cyperus rotundus* L.) and lesser fimbristylis [*Fimbristylis miliacea* L. (Vahl.)]. Significant genotypic differences in competitiveness against weeds were observed. Weed-competitive index was the highest (1.5) for 'IR 84899-B-183-CRA-19-1' and the lowest (0.43) for 'IR 83376-B-B-24-2'. Grain-yield reduction among the cultivars due to weed competition varied from 6.6% in 'IR 82870-11' to 30.4% in 'Sahbhagi Dhan' during 2013 and 6.5% in 'IR 82870-11' to 52.3% in 'Shusk Samrat' during 2014. Across the weed pressure, rice genotype 'IR 84899-B-183-CRA-19-1' (2.75 and 2.28 t/ha) had higher grain yield during both the years. The advanced breeding line 'IR 84899-B-183-CRA-19-1' and the released variety 'CR Dhan 40' had superior weed-suppressing ability, while 'IR 83387-B-B-27-4' had the higher weed tolerance. Pre-emergence application of pendimethalin *fb* post-emergence application of bispyribac-sodium and hand-weeding significantly reduced the weed infestation and resulted in higher yield and profits in dry direct-seeded rainfed upland rice.

Key words : Economics, Herbicides, Rice genotypes, Weeds, Yield

Rice is grown under diverse ecologies ranging from irrigated to rainfed upland, lowland and deep water. Traditional crop-establishment method of rice such as puddling and transplanting requires large amount of water, energy and labour, which are becoming increasingly scarce and expensive (Mishra and Singh, 2012a), making rice production less profitable. Direct-seeded upland rice is becoming more popular as an alternative to transplanted rice, as it is more remunerative if the crop is managed properly (Sharma *et al*., 2007). As the direct-seeding of rice facilitates timely sowing of subsequent wheat, even a slight loss in rice productivity is compensated by increased wheat yields, implying no loss in system productivity (Mishra and Singh, 2012b). However, direct seeded rice (DSR) is subjected to much higher weed pressure than the conventional transplanted systems because of simultaneous emergence of rice and weeds and absence of standing water at the early stage of crop to suppress weed growth. Weeds in DSR compete for moisture, nutrients, light, and space, and reduce the grain yield by 50 to 91% (Rao *et al*., 2007) depending on the severity of infestation. Thus, efficient and timely weed control is crucial for the success of DSR.

Hand-weeding is the most common method to suppress weeds in rice in eastern India. Scarcities of labour for timely weeding and high labour cost are the major limitations of hand-weeding. Herbicides are considered to be an alternative/ supplement to hand-weeding. The increasing herbicide cost, non-availability to small-holder farmers at the time of need, lack of knowledge and skill of correct use of herbicides are the major concerns of farmers to reduce reliance on herbicide usage (Mishra *et al*., 2015). Although, DSR is a weak competitor against weeds,

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evaluation and identification of superior weed competitive rice genotypes may be an attractive, cost-effective and safe approach for sustaining rice productivity, particularly for resource-poor farmers of rainfed ecosystem of eastern India (Patni and Guru, 2012). Screening weed-competitive genotypes could offer an opportunity for using them as a component of integrated weed-management strategies in DSR (Mahajan *et al*., 2014). Competitive genotypes are characterized by high leaf-area index (LAI), high-tillering ability, and fast growth, that is, taller plants at an early stage (Caton *et al*., 2003). Variation in competitive ability against weeds among rice genotypes offers opportunities to select and breed for competitive cultivars that can be adopted by the farmers as a part of integrated weed-management programme. The present investigation was, therefore, undertaken to evaluate the response of rice genotypes to different weed-management levels in dry direct-seeded conditions.

MATERIALS AND METHODS

Field experiments were conducted during the rainy seasons of 2013 and 2014 at the ICAR Research Complex for Eastern Region, Patna (25° 30' N, 85° 15' E and 52 m above mean sea-level) in rainfed drought-prone ecosystem. The total rainfall received during the cropping season (June–October) was 715.7 and 911.5 mm in 2013 and 2014 respectively (Fig. 1). The soil was clay loam (42% sand, 35% silt and 23% clay), low in organic carbon (0.46%), and N (212 kg/ha), and medium in available phosphorus (26 kg P_2O_5/ha) and potassium (215 kg K_2O/ha). The experiment consisted 2 levels of weed pressure, viz. low weed pressure [pendimethalin 1.0 kg/ha as pre-emergence followed by (fb) bispyribac-sodium 30 g/ha at 20 days after sowing (DAS) and 2 hand-weedings each at 45 and 65 DAS] and medium weed pressure (pendimethalin 1.0 kg/ha at 2 DAS) as the main-plot treatments, and 9 rice genotypes including 4 drought-tolerant released varieties, viz. 'Sahbhagi Dhan', 'Sushk Samrat', 'CR Dhan 40', 'Abhishek', and 5 advanced breeding lines, viz. 'IR 84899-B-183-CRA-19-1', 'IR 83387-B-B-40-1', 'IR 82870-11', 'IR 83387-BB-27-4' and 'IR 83376-B-B-24-2' as the sub-plots, was replicated thrice in a split-plot design. Dry seeding of different rice genotypes was done manually on 6 June in 2013 and 11 June in 2014 in rows, 20 cm apart, using seed rate of 25 kg/ha. The size of each plot was 25m² (5 m × 5 m). In order to ensure the proper seed germination, seed priming (overnight soaking of seed followed by drying in shades before sowing) was done before sowing. The seeds were treated with bavistin fungicide at 2.0 g/kg seed before sowing. A recommended dose of fertilizer (80, 40, 20 and 25 kg/ha N, P_2O_5, K_2O and $ZnSO_4$) was applied. Total quantity of phosphorus, potassium and zinc was applied basal, whereas nitrogen was applied in 3 equal splits-each at 14 DAS, maximum tillering and panicle initiation. Pendimethalin 1.0 kg/ha (pre-emergence) was sprayed the next day after sowing with knapsack sprayer fitted with flat-fan nozzle using 500 litres/ha spray volume. Bispyribac-sodium @ 30 g/ha was applied at 4-6 leaf stage (20 DAS). Hand-weeding was done at 45 and 65 DAS.

Weed count, for estimating weed density, and total weed dry weight was recorded at 60 DAS with the help of a quadrate (0.5 m × 0.5 m) placed randomly at 4 places in each plot. Weeds within each quadrat were uprooted, separated species wise and counted. Competitiveness was measured as weed competitive index (CI) and calculated as per Rezakhanlou *et al.*, (2012).

$$CI = [V_{infest}/V_{mean}] / [W_i/W_{mean}]$$

where V_{infest} is the yield of variety (i) in terms of weed infested; V_{mean} is the average yield of all varieties in the presence of weed; W_i is the weed biomass varieties of i; W_{mean} is the average weed biomass is mixed with all varieties.

Leaf-area index (LAI), chlorophyll content and photosynthetic rate were also estimated. Leaf area was measured at 30 and 60 DAS by removing all the leaves from each of 5 randomly selected plants from each plot and passing them individually through a stationary leaf area meter (Model: LI-COR 310). The chlorophyll content was measured as per the procedures given by Hiscox and Israelstam (1979) and expressed as mg/g dry weight. Rate of photosynthesis was measured on fully-expanded flag leaves using portable Infrared Gas Analyzer (LI-6400 Model) and expressed as µmol/m²/second.

The economics was calculated on the basis of minimum support price declared by the Government of India for the rainy season paddy. Net income was calculated as the difference between gross income and total cost. Benefit: cost ratio was worked out by dividing gross returns with a total cost of cultivation. Data were analyzed with Statistix 8.1 for analysis of variance (ANOVA). Treatments were compared by computing the 'F-test'. The significant differences between treatments were compared by critical difference at the 5% level of probability.

RESULTS AND DISCUSSION

Weed-species composition and growth

The major weeds associated with dry direct-seeded rice during both the years were barnyard grass (*Echinochloa colona*), horse purselane (*Trianthema portulacastrum*), native gooseberry (*Physalis minima*), purple nutsedge (*Cyperus rotundus*) and lesser fimbristylis (*Fimbristylis miliacea*) (Table 2). Pre-emergence application of

Table 1. Characterizations of the rice genotypes used for the trials during 2013 and 2014

Rice genotypes	Pedigree	Year of release and place	Grain type	Plant height (cm)	Days to 50% flowering	Maturity duration (days)
'Sahbhagi Dhan'	IR 55419- 04*2. Way Rarem (IR 55419-04 (IR 12979-24-1 (Brown)/UPRLRi5)	2009, CRURRS, Hazaribagh	Long bold	100–110	85–90	110–115
'Shusk Samrat'	C 1064- 5/Kalari/IR 54	2007, NDUAT, Faizabad	Long slender	95–100	80–85	105–110
'CR Dhan 40'	N 22/RP 20-5	2008, CRURRS, Hazaribagh	Short bold	105–115	70–75	100–105
'Abhishek'	CR 314-5-10 (Open Florat mutant)	2007, CRURRS, Hazaribagh	Short bold	95–100	90–95	120–125
'IR 84899-B-183-CRA-19-1'	IR78877-208-B-1-1 X IRRI 132	Advanced breeding lines	Short bold	110–115	85–90	115–120
'IR 83387-B-B-40-1'	IR 72022-46-2-3-3-2/'Sambha Mahsoori'	Advanced breeding lines	Long bold	105–110	85–90	115–120
'IR 82870-11'	IR 82851-16/IR 82855-9	Advanced breeding lines	Long bold	90–95	90–95	120–125
'IR 83387-B-B-27-4'	IR72022-46-2-3-3-2 X 'Sambha Mahsuri'	Advanced breeding lines	Long bold	90–95	85–90	115–120
'IR 83376-B-B-24-2'	IR 71700-247-1-1-2/IR 77080-B-34-1-1	Advanced breeding lines	Long slender	100–105	85–90	115–120

CRURRS, Central Rainfed Upland Rice Research Station; NDUAT, Narendra Deva University of Agriculture and Technology

pendimethalin followed by post-emergence application of bispyribac-sodium and hand weeding (low weed pressure) significantly reduced the infestation of all the weeds as compared to pendimethalin alone (medium weed pressure). The response of rice genotypes in respect of density of individual weeds varied. Significantly lower density of *E. colona*, *T. portulacastrum* and *C. rotundus* was recorded with 'CR Dhan 40', 'IR 82870-11' and 'IR 83387-B-B-27-4' respectively. During 2013, the lowest total weed density and weed biomass was recorded with 'IR 84899-B-183-CRA-19-1' (Table 3). Although 'CR Dhan 40' resulted in lower total weed density (54/m^2) during 2013, it produced the maximum weed biomass (214 g/m^2) due to higher infestation of *P. minima.*

The weed infestation in terms of weed density and weed-dry weight was higher in 2014 than that in 2013. Higher rainfall (911.5 mm) and number of rainy days (63) during 2014 allowed several flushes of weeds to emerge and grow vigorously as compared to 2013 (715.7 mm and 45 days) (Fig. 1). Pre-emergence application of pendimethalin *fb* post-emergence application of bispyribac-sodium and hand weeding significantly reduced the infestation of all the weeds as compared to pendimethalin alone (Table 3). Less effectiveness of weeding during 2014 was attributed to the higher weed growth due to favourable weather conditions for weed growth. Weed dry weight was drastically lower under low weed pressure than that of medium one for all the genotypes except 'IR 83387-B-B-40-1' during both the years. This might be due to higher density of *E. colona* and *T. portulacastrum* (Table 2) which showed their dominance in spite of post-emergence application of bispyribac-sodium and hand-weeding, and resulted in the highest weed dry weight during both the years. There were significant differences among cultivars in their ability to reduce weed dry weight. Among different genotypes, the minimum

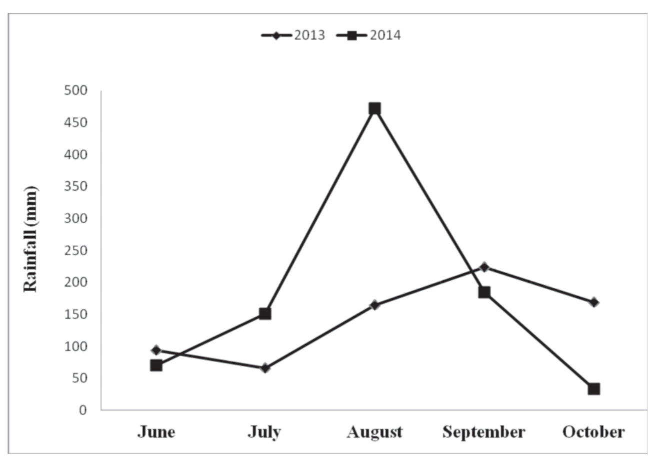

Fig. 1. Rainfall status during cropping season (June–October) in year 2013 and 2014

weed dry weight (85 g/m^2) was recorded with 'IR 84899-B-183-CRA-19-1' during 2013. However, in 2014 'Abhishek' recorded the lowest weed dry weight (341 g/m^2) followed by 'IR 83387-B-B-27-4'. Because of the taller plants and higher LAI, 'IR 84899-B-183-CRA-19-1' had the lower weed dry weight.

Weed-competitive index was the highest for 'IR 84899-B-183-CRA-19-1' and the lowest (0.43) for 'IR 83376-B-B-24-2'. Other genotypes, viz. 'Abhishek', 'IR 83387-B-B-40-1', 'IR 82870-11', 'CR Dhan 40', 'Shusk Samrat' and 'Sahbhagi Dhan' had higher weed competitive index than 'IR 83376-B-B-24-2' (Fig. 2). The high performance of these genotypes in terms of weed-competitive index could be attributed to less weed biomass observed due to their ability to suppress weeds.

Rice growth and yield attributes

Growth in terms of plant height, plant dry biomass and leaf-area index (LAI), and yield attributes, viz. panicles/m^2, 1,000-seed weight, were significantly higher under low weed pressure compared than medium weed pressure (Table 4). This might be due to severe infestation of weeds under medium weed pressure that might have restricted the nutrient and moisture supply required for the proper pollination and seed setting in the rice plants. Days to 50% flowering and plant height (at 30 DAS) did not differ significantly between the weeding levels. However, plant height at 60 DAS was significantly higher under low weed pressure. Plant height has often been described as one of the most important factors for weed competitive-ability of crop (Caton *et al*., 2003). Higher plant height significantly contributes superior weed competitive ability. Irrespective of weeding level, maximum plant height was recorded with 'CR Dhan 40', followed by 'IR 84899-B-183-CRA-19-1'. The LAI at 30 and 60 DAS was significantly higher with low weed pressure than medium weed pressure level. Among the genotypes, 'IR 84899-B-183-CRA-19-1' (3.16), *fb* 'IR 83387-B-B-27-4' (3.06) and 'CR Dhan 40' (2.98) produced higher LAI at 60 DAS and suppressed the weed growth. Among the rice genotypes, although IR 83387-B-B-27-4 was shorter than the 'CR Dhan 40', the farmer produced higher LAI due to more number of tillers/plant that resulted in better weed suppression. Higher weed pressure significantly reduced the number of panicles/m^2, rice dry biomass, 1,000-seed weight, and increased grain sterility percentage. Across the genotypes, the maximum number of panicles was recorded in 'IR 83376-B-B-24-2' followed by 'Abhishek'. Higher plant dry biomass also recorded in 'IR 83376-B-B-24-2' fol-

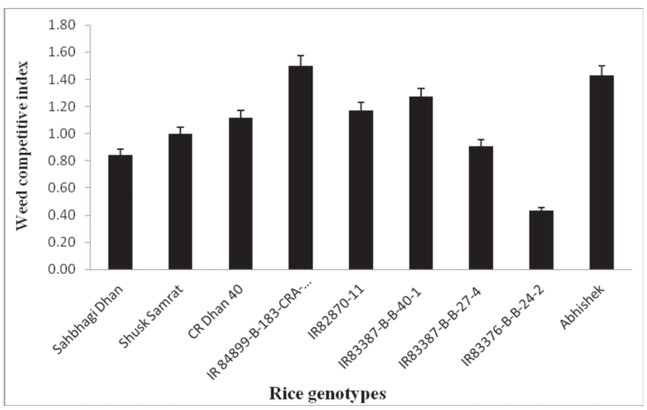

Fig. 2. Weed competitive index of different rice genotypes

Table 2. Effect of weed–control treatment and genotypes on weed-species composition (mean data of 2 years)

Treatment	*Echinochloa colona*	*Trianthema portulacastrum*	*Physalis minima*	*Cyperus rotundus*	*Fimbristylis miliacea*	Others
Weed pressure level						
Low weed pressure	27	28	19	15	19	48
Medium weed pressure	55	55	31	44	31	24
SEm±	6	4	1	3	2	5
CD (P=0.05)	24	16	5	12	11	16
Genotypes						
'Sahbhagi Dhan'	50	43	27	34	24	16
'Shusk Samrat'	38	48	21	28	27	75
'CR Dhan 40'	27	40	27	33	26	68
'IR 84899-B-183-CRA-19-1'	36	38	21	27	27	20
'IR 82870-11'	40	31	27	33	26	26
'IR 83387-B-B-40-1'	51	50	22	24	21	45
'IR 83387-B-B-27-4'	33	37	28	21	21	52
'IR 83376-B-B-24-2'	50	40	25	37	25	66
'Abhishek'	36	42	24	31	27	64
SEm±	4	4	2	3	2	6
CD (P=0.05)	12	14	NS	9	NS	19

lowed by 'IR 83387-B-B-27-4'. The grain sterility percentage was significantly higher under medium weed pressure than low weed pressure. It was positively correlated with weed dry matter (Fig. 3). Among genotypes, the minimum grain sterility was recorded in 'Abhishek' and the maximum in 'Sushk Samrat'. Grain sterility is one of the major components in yield. Higher grain sterility in medium weed pressure may be due to insufficient moisture condition and higher weed growth. Effective weed control with herbicides and hand-weeding significantly reduced the grain sterility percentage.

Chlorophyll content and photosynthetic rate were significantly higher under low weed pressure level. Among the genotypes, 'IR 83387-B-B-27-4' had the higher chlorophyll content followed by 'Shusk Samrat' and 'IR 82870-11' had the lowest. Maintenance of leaf chlorophyll under weedy situations is an important character for the

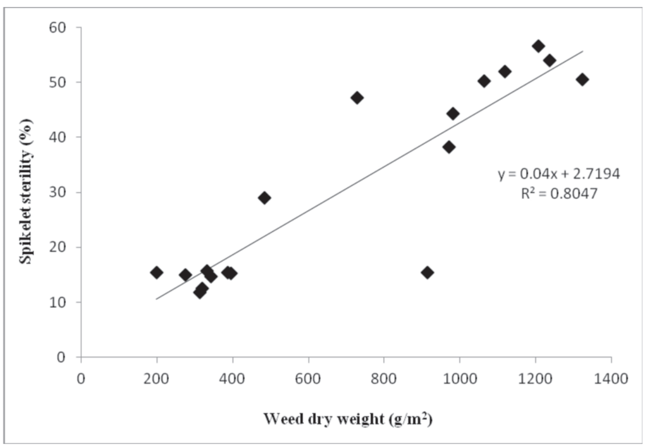

Fig. 3. Relationship between spikelet sterility and weed dry weight at 60 days after sowing

competitiveness of the rice plants (Inamura *et al*., 2003). Maintenance of high photosynthetic rate is necessary to get higher crop yields. Photosynthetic rate among the rice genotypes differed significantly under both weeding levels. Irrespective of weed pressure level, the highest photosynthetic rate was observed with 'IR 83387-B-B-27-4' *fb* 'IR 84899-B-183-CRA-19-1 and 'Shusk Samrat' (Table 4). The highest reduction in photosynthetic rate under weedy situation was observed with genotype 'IR 82870-11' followed by 'Abhishek'. Increase in chlorophyll content is correlated with an increase in the net photosynthetic rate (Ibrahim *et al*., 2011).

Grain yield

Yield is an important indicator to access the competitive ability of rice genotypes. Irrespective of the treatments, rice grain yield was higher during 2013 than 2014 mainly owing to lower weed competition (Table 5). Averaged across cultivars, low weed pressure (pre-emergence application of pendimethalin *fb* post-emergence application of bispyribac-sodium and hand-weeding) resulted in 22% more grain yield in 2013 and 48% in 2014 than the medium weed pressure (pendimethalin alone). Rice genotypes differed significantly for grain yield under different weed pressure levels. In present study, the yield reduction among cultivars due to weed competition varied from 6.6% in 'IR 82870-11' to 30.4% in 'Sahbhagi Dhan' during 2013 and 6.5% in 'IR 82870-11' to 52.3% in 'Shusk Samrat' during 2014, though 'IR 82870-11' resulted in very poor grain yield during 2014. Across the weed pressure, genotype IR 84899-B-183-CRA-19-1 had higher grain yield during both the years. Grain yield was negatively correlated with weed dry weight (Fig. 4). Based on

Table 3. Effect of weed control and genotypes on weed density and dry biomass (60 DAS) of weed during 2013 and 2014

Rice genotypes	2013						2014					
	Weed density (Nos./m²)			Weed dry weight (g/m²)			Weed density (Nos./m²)			Weed dry weight (g/m²)		
	W1	W2	Mean	W1	W2	Mean	W1	W2	Mean	W1	W2	Mean
'Sahbhagi Dhan'	29	76	53	51	172	112	344	326	335	343	1324	834
'Shusk Damrat'	43	90	67	64	195	130	264	552	408	396	1207	802
'CR Dhan 40'	49	59	54	55	214	135	294	481	388	332	1237	785
'IR 84899-B-183-CRA-19-1'	48	56	52	52	117	85	212	361	287	275	981	628
'IR 82870-11'	50	70	60	62	181	122	133	477	305	314	1065	690
'IR 83387-B-B-40-1'	39	81	60	148	157	153	310	422	366	914	972	943
'IR 83387-B-B-27-4'	-	-	-	-	-	-	279	304	292	319	729	524
'IR 83376-B-B-24-2'	-	-	-	-	-	-	310	375	343	387	1120	754
'Abhishek'	-	-	-	-	-	-	273	375	324	198	484	341
Mean	43	81		72	173		269	408		386	1013	
CD (P=0.05)	W = 24				W = 42				W = 110		W = 588	
	G = 22				G = 38				G = 54		G = 398	
	W × G =81				W × G =132				W × G =122		W × G = 738	

W_1, Low weed pressure; W_2, medium weed pressure

2 years mean data, rice genotypes ‘Shusk Samrat’ and ‘IR 84899-B-183-CRA-19-1’ performed better under low and medium weed pressure respectively. Because of more plant height and LAI, ‘IR 84899-B-183-CRA-19-1’ resulted in better suppression of the weed growth than the other genotypes and gave more grain yield under medium weed pressure condition. Under low weed pressure condition, ‘IR 84899-B-183-CRA-19-1’ and ‘IR 83387-B-B-27-4’ gave higher grain yield 3,064 kg/ha and 2,991 kg/ha during 2013 and 2014 respectively. Mahajan *et al*. (2015) also observed genotypic variations in rice for grain yield and weed competition. Cultivar–weed competitiveness is a complex attribute that involves the ability of the cultivar to maintain yields despite the high weed pressure (weed tolerance) and the ability to suppress weed growth (Jannik *et al*., 2000). Weed-suppressive ability reduces weed seed production and benefits weed management in long term, while weed tolerance only benefit yield in the current

Table 4. Effect of weed control treatment on growth and yield attributes of rice genotypes (mean data of 2 years)

Treatment	DFF	Plant height (cm)		Leaf-area index		Chlorophyll content (mg/g)	Photo-synthetic rate (μmol/m²/second)	Tillers/m²	Rice dry biomass (g)/m²	1,000-seed weight (g)	Spikelet sterility (%)
		30 DAS	60 DAS	30 DAS	60 DAS						
Weed pressure level											
Low weed pressure	99	30	91	1.55	2.79	3.60	24.26	156	1,180	29.0	14
Medium weed pressure	98	28	70	1.11	2.10	3.38	21.82	99	861	23.2	49
SEm±	1	1		0.12	0.04	0.07	0.22	2	17	1.4	7
CD (P=0.05)	NS	NS	3	0.35	0.10	0.20	0.65	6	52	3.9	21
Genotypes											
‘Sahbhagi Dhan	96	29	77	1.33	1.86	3.33	22.60	127	959	23.5	33
‘Shusk Samrat	97	26	79	1.16	1.92	4.12	25.75	130	726	27.5	36
‘CR Dhan 40	84	25	98	1.28	2.98	3.74	23.70	102	952	23.5	35
‘IR 84899-B-183-CRA-19-1’	86	29	90	1.37	3.16	3.93	26.06	124	985	25.2	30
‘IR 82870-11’	103	32	81	1.13	1.89	2.32	19.07	120	1,063	28.2	27
‘IR 83387-B-B-40-1’	103	29	87	1.30	2.21	3.25	20.94	111	1,109	26.9	30
‘IR 83387-B-B-27-4’	107	31	57	1.70	3.09	4.56	26.63	134	1,195	27.6	34
‘IR 83376-B-B-24-2’	109	27	73	1.47	2.37	3.55	22.63	152	1,239	26.8	31
‘Abhishek’	108	32	82	1.22	2.52	3.14	20.55	151	963	25.8	22
SEm±	1	1	0.40	0.04	0.06	0.07	0.40	1	125	1.2	6
CD (P=0.05)	2	3	1	0.11	0.16	0.22	1.11	3	387	3.5	17

DFF, Days to 50% flowering

Table 5. Effect of weed-control treatment on grain yield (kg/ha) of rice genotypes

Rice genotypes	2013			2014		
	W1	W2	Mean	W1	W2	Mean
‘Sahbhagi Dhan’	3,034	2,111	2,572	2,418	1,239	1,829
‘Shusk Samrat’	2,999	2,339	2,669	2,868	1,367	2,117
‘CR Dhan 40’	2,623	2,452	2,538	2,172	1,848	2,010
‘IR 84899-B-183-CRA-19-1’	3,064	2,438	2,751	2,624	1,931	2,278
‘IR 82870-11’	2,716	2,537	2,627	1,426	1,333	1,380
‘IR 83387-B-B-40-1’	2,959	2,322	2,641	1,988	1,483	1,736
‘IR 83387-B-B-27-4’	-	-	-	2,991	1,756	2,273
‘IR 83376-B-B-24-2’	-	-	-	2,263	1,278	1,771
‘Abhishek’	-	-	-	2,062	1,833	1,948
Mean	2,899	2,367	-	2,312	1,563	-
CD (P=0.05)		W = 235			W = 350	
		G = 187			G = 370	
		W × G = 210			W × G = 523	

W1, Low weed pressure; W2, medium weed pressure

Table 6. Effect of weed-control treatment and cultivars on economic return in (mean data of 2 years)

Rice genotypes	Net returns (₹/ha)			Benefit: cost ratio		
	W1	W2	Mean	W1	W2	Mean
'Sahbhagi Dhan'	15,842	5,852	10,847	2.17	1.47	1.82
'Shusk Samrat'	17,791	7,549	12,670	2.31	1.61	1.96
'CR Dhan 40'	12,293	11,099	11,696	1.91	1.90	1.90
'IR 84899-B-183-CRA-19-1'	16,956	11,339	14,147	2.25	1.91	2.08
'IR 82870-11'	7,454	9,293	8,373	1.55	1.75	1.65
'IR 83387-B-B-40-1'	13,233	8,312	10,772	1.98	1.67	1.82
'IR 83387-B-B-27-4'	18,076	6,844	12,460	2.33	1.55	1.94
'IR 83376-B-B-24-2'	10,319	1,011	5,665	1.76	1.08	1.42
'Abhishek'	8,560	7,027	7,794	1.63	1.56	1.60
Mean	13,391	7,592	-	1.99	1.61	-
CD (P=0.05)		W = 4,825			W =0.36	
		G = 3,775			G = 0.28	
		W × G = 6522			W × G = 0.49	

W_1, Low weed pressure; W_2, medium weed pressure

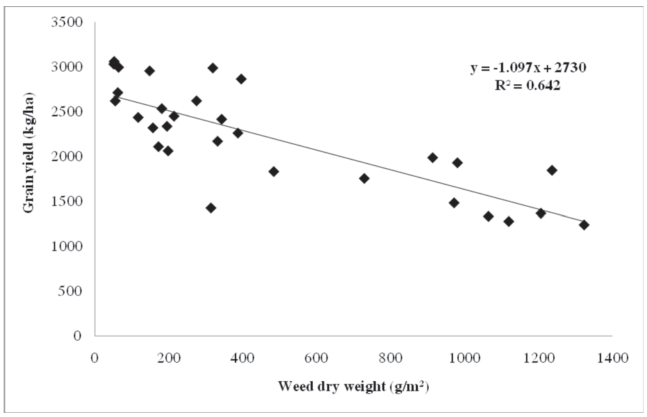

Fig. 4. Relationship between grain yield and weed dry weight at 60 days after sowing

growing season and may result in increased weed pressure in the future. However, strong weed suppressive ability does not guarantee a high yield under weed competition if the yield potential is low (Zhao *et al*., 2006).

Economic analysis

The low weed pressure plots had 43% higher net income than the medium weed pressure plot due to higher grain yields. Among the rice genotypes, 'IR 84899-B-183-CRA-19-1' had the highest net income and benefit: cost ratio irrespective of the weeding levels (Table 6). Among the genotypes, 'IR 83387-B-B-27-4' and 'Shusk Samrat' in low weed pressure and 'IR 84899-B-183-CRA-19-1' and 'CR Dhan 40' in medium weed pressure had the higher net income and benefit: cost ratio. Under medium weed pressure, 'IR 83376-B-B-24-2' had the lowest net return and benefit: cost ratio because of its poor yield. The sale prices of the produce for different genotypes were the same, thus, the difference in net income was largely due to variation in yield levels and cost of weeding.

The results of our study revealed that the advanced breeding line 'IR 84899-B-183-CRA-19-1' and the released variety 'CR Dhan 40' had superior weed-suppressing ability, while 'IR 83387-B-B-27-4' had higher weed tolerant ability. Pre-emergence application of pendimethalin *fb* post-emergence application of bispyribac-sodium and hand-weeding significantly reduced the weed infestation and resulted in higher yield and profits in dry direct-seeded rainfed upland rice. The study also indicates that plant height and leaf-area index are the major weed competitive traits that can be explored for direct-seeded rice.

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