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Evaluation of weed competitiveness of direct-seeded rice (*Oryza sativa)* genotypes under different weed management practices

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ABSTRACT

Performance of eight rice (*Oryza sativa* L.) genotypes ('Swarna Shreya', 'IR84899-B-179-13-1-1-1','IR83929-B-B-291-2-1-1-2','DRR-42','IR84899-B-183-20-1-1-1','IR84894-143-CRA-17-1','DRR-44','Rajendra Bhagwati') was evaluated in three weed management practices, i.e. application of pendimethalin @1.0 kg/ha as pre-emergence (PE) at 2 days after sowing (DAS) followed by (*fb*) bispyribac-Na @30 g/ha as post-emergence (POE) at 20 DAS and two hand weedings (40 and 60 DAS)-low weed pressure; application of pendimethalin @ 1.0 kg/ha as PE *fb* bispyribac-Na @ 30 g/ha as POE at 20 DAS-medium weed pressure and pendimethalin @ 1.0 kg/ha alone-high weed pressure during rainy seasons of 2016 and 2017 at Patna, Bihar. Application of pendimethalin (PE) followed by bispyribac-Na (POE) and two hand weedings (low weed pressure) significantly reduced weed infestation compared to pendimethalin alone (medium weed pressure). Markedly lower weed density was recorded with 'IR84899-B-179-13-1-1-1'. Low weed pressure produced 90 and 26% more grain yield (2.53 t/ha) compared to medium (2.01 t/ha) and high weed pressure (1.33 t/ha).Significantly higher grain yield was recorded with 'IR84899-B-179-13-1-1-1' (2.32 t/ha) followed by 'Swarna Shreya' (2.18 t/ha). Low weed pressure had significantly higher gross returns (45.9×10^3 ₹/ha) and net returns (14.1×10^3 ₹/ha). Amongst genotypes, 'IR84899-B-179-13-1-1-1' had the highest gross returns (44×10^3 ₹/ha) and net income (17.6×10^3 ₹/ha). Hence, it may be concluded that application of pendimethalin (PE) *fb* bispyribac-Na (POE) along with hand weeding had significant impact on reduction of weed infestation and helps in achieving the higher grain yield of direct-seeded rice genotypes in eastern India.

Key words: Direct-seeded rice, Economics, Herbicides, Rice genotypes, Weeds, Yields

Rice (*Oryza sativa* L.) is grown under the diverse agro-ecologies ranging from irrigated to upland rainfed, lowland and deep water ecosystem in India (Kumar *et al*. 2016a).It is the most important staple food crop for more than half of world's population (Kumar *et al.* 2016b). In India, it occupies ~43.8 m ha and production of ~105 mt with the productivity of ~2.24 t/ha, respectively (Kumar *et al*. 2017a). It is estimated that by 2025 AD, its requirement would be ~140 mt in India (Kumar *et al*. 2019a). To sustain the present food self-sufficiency and future food requirements, India has to increase its productivity by ~3%/annum (Kumar *et al.*2018). Conventional methods of rice establishment is the manual transplanting of seedling into puddled soil, which requires huge water, energy, labours, that is increasingly scarce and expensive (Bohra and Kumar 2015). Thus, continuous puddling of rice fields over decades led to deterioration of soil-physical properties (Kumar *et al*. 2015). Direct-seeded rice (DSR) is subjected to intense weed pressure compared to transplanted puddle system, as simultaneous emergence of crop and weeds in absence of standing water at initial crop stages to suppress weeds. Weeds in DSR competes for moisture, nutrient, light, space, reduce yields by 50 to 91% depending upon severity of weeds (Kumar *et al*. 2016a). Thus, efficient weed control is crucial for successful production of DSR (Kumar *et al*. 2016b). Scarcities of labours for timely weeding and their higher costing are major limitation of hand weeding (Kumar *et al.* 2019b). Herbicides are considered to be an alternative to the hand weeding. Increasing herbicide cost, non-availability to small-holder farmers at time of need, lack of knowledge and correct use of herbicides are major the concerns to reduce the reliance on herbicide usages. Although, DSR is a weak competitor against weeds infestations, hence evaluation and identification of superior weed competitive DSR genotypes may be an attractive, cost-effective and safe approach for resources poor farmers (Kumar *et al*. 2016a). Thus, screening weed-competitive genotypes could offer an opportunity for using them as component of integrated weed management strategies in successful production of DSR. The present investigation was therefore, undertaken to evaluate the weed competitive

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ability of direct-seeded rice genotypes under the different weed management practices.

MATERIALS AND METHODS

Field experiment was conducted during rainy seasons of 2016 and 2017 at the ICAR- Research Complex for Eastern Region, Patna (25°30`N latitude, 85°15`E longitude and 52 m amsl) under rainfed agro-ecosystem. Total rainfall received during cropping season (June-October) were 977 and 840 mm in 2016 and 2017, respectively. Experimental site was clay-loam in texture (42.3% sand, 34.7% silt and 23% clay), low in organic carbon (0.44%), and N (215 kg/ha), and medium in available P (22 kg P_2O_5/ha) and K (218 kg K_2O/ha). Experiment was consisted of three levels of weed management, *viz*. low weed pressure (pendimethalin @ 1.0 kg/ha as pre-emergence (PE) at 2 days after sowing (DAS) followed by (*fb*) bispyribac-Na @ 30 g/ha as post-emergence (POE) at 20 DAS and two hand weedings at 40 and 60 DAS); medium weed pressure (Pendimethalin @ 1.0 kg/ha as PE at 2 DAS *fb* bispyribac-Na @ 30 g/ha as POE at 20 DAS; and high weed pressure (pendimethalin @ 1.0 kg/ha alone as PE at 2 DAS) as main-plot, and eight rice genotypes including four released varieties, *viz*. 'Swarna Shreya', 'DRR 42','DRR 44','Rajendra Bhagawati' and four advanced breeding lines, *viz*.'IR84899-B-179-13-1-1-1', 'IR83929-B-B-291-2-1-1-2', 'IR84899-B-183-20-1-11','IR84894-143-CRA-17-1' as sub-plot and replicated thrice in split-plot. Dry seeding of rice was done manually on 10 June in 2016 and 14 June in 2017 in rows of 20 cm. Recommended dose of fertilizer (RDF), i.e. 80-40-20 kg/ha N-P_2O_5-K_2O was applied. Whole quantity of P and K were applied as basal, whereas, N was applied in three equal splits (basal, maximum tillering, panicle initiation stages). Pendimethalin @ 1.0 kg/ha was sprayed in next day after sowing and bispyribac-Na @ 30 g/ha was applied at 4-6 leaf stages. Hand weeding was done in standing crop at 40 and 60 DAS. Weed count and total weed dry weight were recorded at 30, 60 and 90 DAS with help of a quadrate (0.5 m × 0.5 m). Weeds within each quadrate were uprooted, counted then subjected to sun drying followed by oven drying at 65^0C for 2-3 days to record weed dry matters. Leaf area index (LAI) was measured at 90 DAS by removing all leaves from five randomly selected plants from each plot and passing them individually through a stationary leaf area meter. Economics was calculated on basis of minimum support price. Net income was calculated as difference between gross income and cost of cultivation. Production and economic efficiency were calculated as suggested by Kumar *et al*. (2015). Grain yields of rice were converted into carbohydrate equivalent as suggested by Gopalan *et al.* (2004). Carbon output was computed based on plant biomass contains on an average ~44% carbon (Lal 2004). Root samples were collected by using root auger up to 30 cm depth at flowering. Thereafter, roots were washed with tap water in perforated sieve with utmost care and then measured in cm with help of scale from base of root to tip of longest root. Total root biomass of three plants was dipped in water kept in a measuring cylinder for recording root volume by water displacement methods. Then displaced water (cc) was measured to represent root volume (Kumar and Kumawat 2015). Data on weeds were square-root transformed before analysis to reduce heterogeneity of variance. Data obtained for 2-years were pooled and statistically analyzed.

RESULTS AND DISCUSSION

Weed dynamics

Major weeds associated with DSR during the

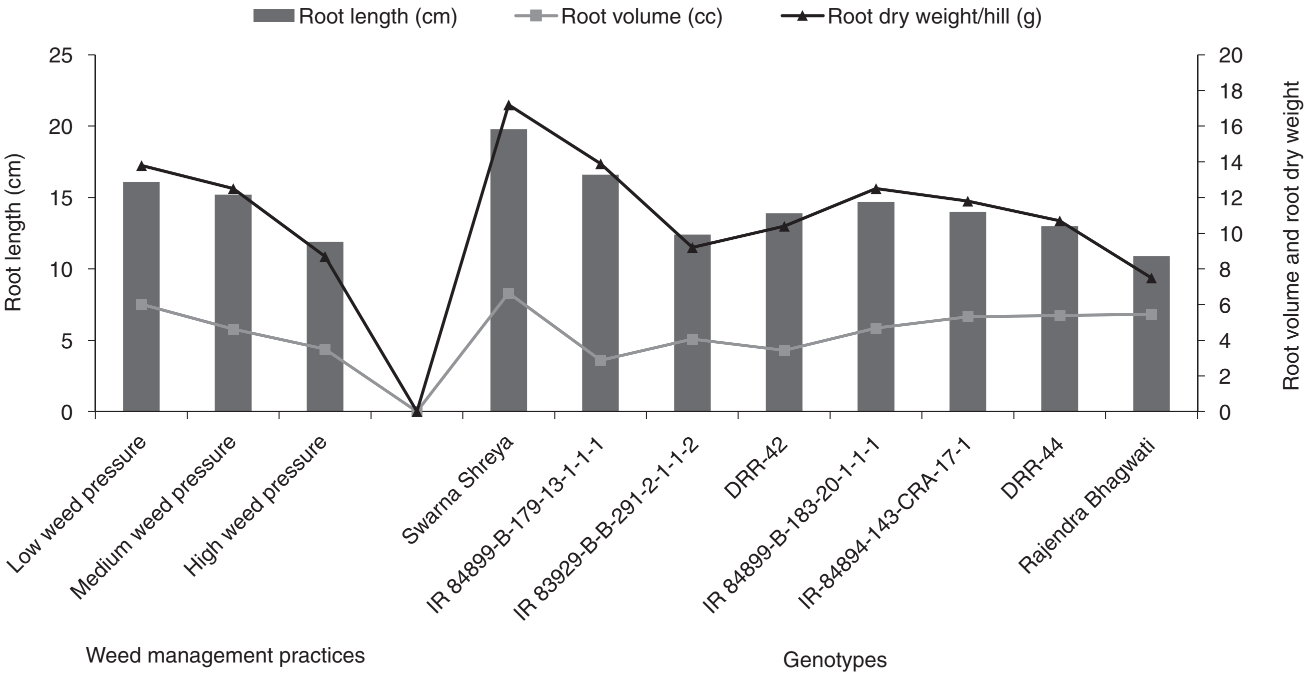

Fig 1 Root attributes as influenced by weed management practices and direct-seeded rice genotypes (Pooled data of 2 years).

Table 1 Weed density and weed dry matters of direct-seeded rice genotypes as influenced by weed management practices (Pooled data of 2 years)

Treatment	Weed density (no./m^2)			Weed dry matter (g/m^2)		
	At 30 DAS	At 60 DAS	At 90 DAS	At 30 DAS	At 60 DAS	At 90 DAS
Weed management practices						
Low weed pressure	15.24 (232.3)	18.82 (353.7)	10.12 (102.41)	5.13 (26.32)	8.90 (79.21)	4.58 (21.0)
Medium weed pressure	16.33 (266.67)	20.21 (408.44)	14.18 (201.10)	7.12 (50.69)	8.30 (68.89)	6.27 (39.3)
High weed pressure	18.25 (333.10)	22.20 (492.84)	20.21 (408.4)	10.09 (101.81)	10.8 (118)	11.24 (124)
LSD (P=0.05)	0.96	1.20	1.04	084	1.20	0.97
Genotypes						
'Swarna Shreya'	16.42 (269.1)	19.03 (362.4)	14.30 (204.6)	6.79 (46.10)	8.85 (78.4)	6.01 (36.10)
'IR 84899-B-179-13-1-1-1'	15.80 (249.5)	17.84 (317.8)	13.52 (182.8)	6.78 (45.96)	8.77 (76.9)	4.33 (18.75)
'IR 83929-B-B-291-2-1-1-2'	16.70 (278.7)	22.89 (523.9)	15.02 (225.7)	6.98 (48.72)	9.58 (91.7)	7.37 (54.31)
'DRR-42'	16.81 (282.7)	19.52 (380.9)	15.35 (235.7)	7.29 (53.14)	8.96 (80.3)	7.23 (52.7)
'IR 84899-B-183-20-1-1-1'	16.70 (278.8)	21.77 (473.9)	15.59 (243.2)	7.67 (58.82)	9.32 (86.9)	8.83 (77.97)
'IR 84894-143-CRA-17-1'	16.96 (287.8)	20.64 (425.9)	15.11 (228.4)	7.89 (62.25)	10.12 (102.5)	6.89 (77.96)
'DRR-44'	16.33 (266.8)	20.45 (419.8)	14.46 (209.2)	7.39 (54.61)	9.28 (86.2)	7.70 (59.29)
'Rajendra Bhagwati'	17.13 (293.6)	21.15 (447.2)	15.33 (235.1)	8.78 (77.10)	9.72 (94.4)	8.9 (79.21)
LSD (P=0.05)	1.28	1.57	1.27	1.05	1.60	1.15

Data subjected to square root transformation ($\sqrt{X+0.5}$), Values in parentheses are original

cropping periods were *Echinochloa colona*, *Trianthema portulacastrum*, *Physalis minia*, *Cyperus rotundus* and *Fimbristylis miliacea*. Application of pendimethalin (PE) followed by bispyribac-Na (POE) and two-hand weeding at 40 and 60 DAS (low weed pressure) reduced the total weed infestation compared to pendimethalin alone (medium weed pressure) at 30, 60 and 90 DAS (Table 1). The low weed pressure declined total weed population to the tunes of 43 and 15%; 39 and 18%; 295 and 96% at 30, 60 and 90 DAS, respectively. This might be due to better weed suppression with efficient weed management (Kumar *et al.* 2016a). Significantly lower weed density was recorded with 'IR84899-B-179-13-1-1-1' followed by 'Swarna Shreya' due to their ability to reduce weed dry weight. The lowest weed dry matter was recorded with 'IR84899-B-179-13-1-1-1' followed by 'Swarna Shreya'. Because of more LAI, 'IR 84899-B-183-CRA-19-1' had lower weed dry matter. Better performance of these genotypes in weed competitiveness in suppressing weeds could be attributed to less weed biomass (Kumar *et al*. 2016b).

Growth attributes

The plant height, dry matter production and leaf area index were markedly influenced with weed management practices (Table 1). All these attributes were recorded significantly with low weed pressure management practices. Plant height has often been described as one of the most important factors for weed competitive ability of the crops (Kumar *et al.* 2016b). Taller plant contributes significant weed competitive ability. Similar trend were followed in case of LAI and dry matter. This might be due to severe weeds infestation with high weed pressure had restricted nutrient and moisture supply for proper crop establishment. Root attributes (root length, root volume, root dry-weight) had marked influence with different levels of weed management (Fig. 1). These attributes had significantly higher with low weed pressure. This might be due to intense weeds loads restricted to proper use of space, nutrient and moisture for better crops (Kumar 2015).

Tallest plant was recorded with 'IR84899-B-179-13-1-1-1' (97.7 cm) followed by 'Swarna Shreya' (93.2 cm), respectively. Similar trends were followed in case of LAI, where 'IR84899-B-179-13-1-1-1' followed by 'Swarna Shreya' had higher LAI and resulted in better suppression of weeds due to higher leaves. Rice genotypes 'IR84899-B-179-13-1-1-1' followed by 'Swarna Shreya'

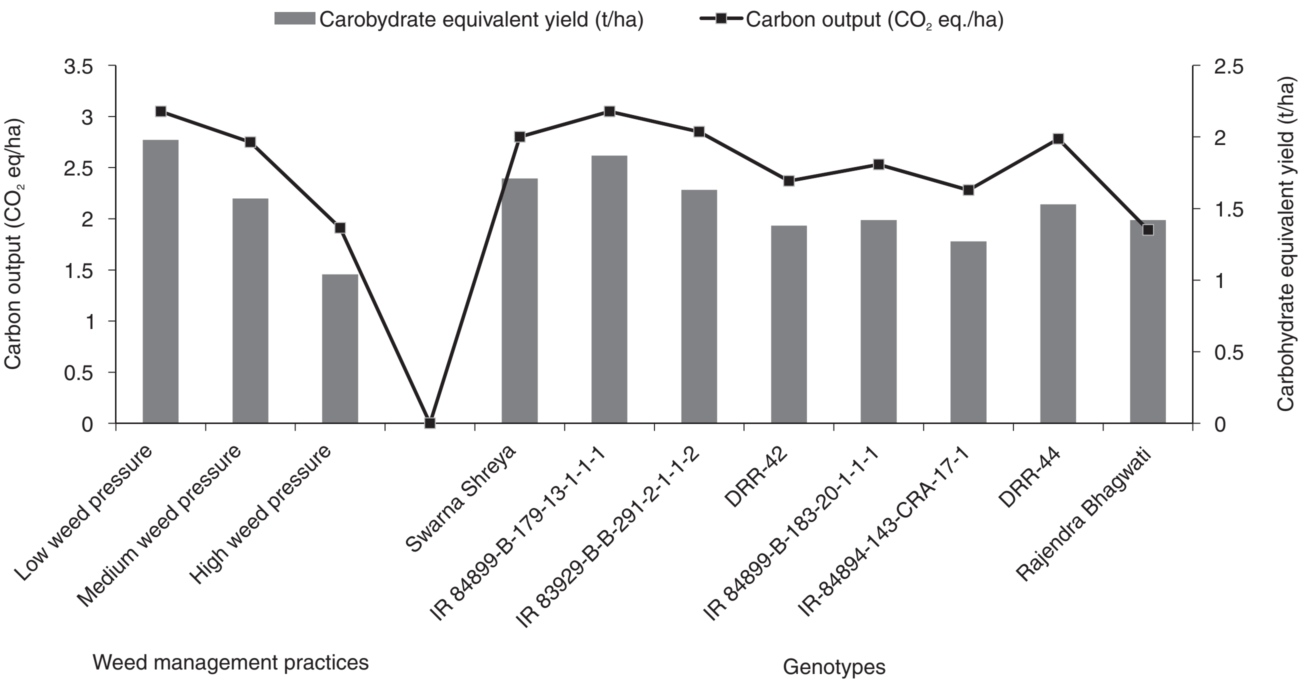

Fig 2 Carbohydrate equivalent yield and carbon output of rice genotypes as influenced by weed management practices (Pooled data of 2 years).

(316) had higher dry matters. This might be due to genotypes had taller plant with more leaves resulted in better weeds suppression and produced more dry matters (Kumar *et al.* 2016a). Root length (17.8 cm), root volume (6.5 cc) and root dry weight (15.2 g) had higher with 'Swarna Shreya'. This might be due genotypic genetic traits.

Yields attributes and yields

Yield attributes, i.e. filled grains/panicle and 1000-grain weight was influenced by weed management practices (Table 2). These attributes had higher with low weed pressure and recorded to increase to the tunes of 71 and 30.7% compared to high weed pressure. Maximum filled grains/panicle (123.6) was recorded with 'IR84899-B-179-13-1-1-1'. 'IR84899-B-179-13-1-1-1' (21.2 g) being on a par with 'Swarna Shreya' (20.6) and 'DRR-42 (19.1) and had higher 1000-grain weight. Differential values of yield attributes among genotypes might be due to genetic traits (Kumar *et al.* 2017a).

Grain yield is an important indicator to access

Table 2 Growth, yield attributes and economics of rice genotypes as influenced by weed management practices (Pooled data of 2 years)

Treatment	Plant height (cm)	Dry matter /m row (g)	Leaf area index	Filled grains/ panicle (no.)	1000-grain weight (g)	Grain yield (t/ha)	Gross returns (×10[3] ₹/ha)	Net returns (×10[3] ₹ ha)	Benefit: cost ratio	Crop productivity (kg/ha/ day)	Economic efficiency (₹/ha/ day)
Low weed pressure	99.6	111.9	3.04	116.3	21.7	2.53	45.9	14.1	1.44	20.7	115
Medium weed pressure	86.8	95.5	2.35	90.5	18.9	2.01	37.6	12.9	1.52	16.3	104
High weed pressure	76.2	80.9	1.67	68.1	16.6	1.33	25.8	3.3	1.14	10.8	20
LSD (P=0.05)	3.0	2.6	0.08	7.8	1.8	0.07	1.20	1.19	0.04	0.5	10
Genotypes											
'Swarna Shreya'	93.2	129.9	2.24	109.8	20.6	2.18	40.2	13.8	1.47	17.6	111
'IR 84899-B-179-13-1-1-1'	97.7	112.6	3.26	123.6	21.2	2.32	44.0	17.6	1.63	19.2	142
'IR 83929-B-B-291-2-1-1-2'	91.2	100.2	2.44	87.2	18.9	2.08	39.0	12.6	1.47	17.4	106
'DRR-42'	81.8	107.4	2.25	76.6	20.3	1.77	32.9	6.5	1.25	14.7	54
'IR 84899-B-183-20-1-1-1'	87.9	83.7	2.24	84.3	19.1	1.82	34.0	7.8	1.29	14.7	63
'IR 84894-143-CRA-17-1'	84.5	100.5	2.15	98.3	17.7	1.63	30.7	4.3	1.15	13.2	35
'DRR-44'	85.6	91.8	2.15	94.4	17.9	2.01	37.0	10.6	1.39	15.8	85
'Rajendra Bhagwati'	78.4	43.1	2.06	59.1	17.7	1.84	33.9	7.4	1.29	14.8	44
LSD (P=0.05)	4.8	4.2	0.13	13.0	2.9	0.11	1.94	1.94	0.07	0.9	16

competitive ability of DSR genotypes. Low weed pressure had (application of PE pendimethalin *fb* POE as bispyribac-sodium and hand weeding) produced 90 and 26% more grain yield (2.53 t/ha) compared to medium (2.01 t/ha) and high weed pressure (1.33 t/ha). Significantly higher crop productivity was recorded with low weed pressure (20.7 kg/ha/day). This might be due to higher grain yields (Kumar *et al*. 2016b). Significantly higher carbohydrate equivalent (1.98 t/ha) and carbon output (3.05 CO_2 eq./ha) were recorded with low weed pressure (Fig 2). This might be due to higher grain and total biomass yields by DSR (Kumar *et al.* 2017b).

Significantly higher grain yield was recorded with 'IR84899-B-179-13-1-1-1' (2.32 t/ha) closely followed by 'Swarna Shreya' (2.18 t/ha). This might be due to more plant height and LAI were associated with 'IR84899-B-183-CRA-19-1' and 'Swarna Shreya' and resulted in better weed suppressing ability and produced more grain yields under low weed pressure (Table 2). Cultivar-weed competitiveness is a complex attribute that involves ability of cultivar to maintain yields despite of high weed pressure (Kumar *et al*. 2016b). Significantly higher carbohydrate equivalent (1.87 t/ha) and carbon output (2.80 CO_2 eq./ha) was recorded with 'IR84899-B-179-13-1-1-1'(Fig 2). This might be due to higher grain yields and total biomass production (Kumar *et al*. 2018).

Profitability

Low weed pressure had significantly higher gross returns (45.9×10^3 ₹/ha), net returns (14.1×10^3 ₹/ha) (Table 2). Low weed pressure plots had 327% higher net returns than that to high weed pressure due to higher yields (Kumar *et al*. 2016). The B: C ratio was significantly higher with medium weed pressure (1.52) might be due to high cost incurred in two hand weedings with low weed pressure (Chatterjee *et al.* 2016, Kumar *et al*. 2017a). Economic efficiency was higher with low weed pressure (₹115/ha/day). This might be due to higher monetary returns (Kumar *et al*. 2018). 'IR84899-B-179-13-1-1-1' had highest gross returns (44×10^3 ₹/ha), net income (17.6×10^3 ₹/ha) and B: C ratio (1.63). 'IR84899-B-179-13-1-1-1' (₹142/ha/day) had higher economic efficiency followed by 'Swarna Shreya' (₹142/ha/day). This might be due to poor yields and net returns (Kumar *et al*. 2017b).

Advanced rice breeding line 'IR84899-B-179-13-1-1-1' and released variety 'Swarna Shreya' had superior in weed suppressing ability. Thus, application of pendimethalin (PE) *fb* bispyribac-sodium (POE) and hand weeding is a better option to reduce the weed infestation and had a higher productivity of DSR in rainfed agro-ecosystem of eastern India.

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