



Effect of cultivars and weed management practices on weeds, productivity and profitability in zero-till direct-seeded rice (*Oryza sativa*)

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ABSTRACT

A field study was carried out during the two consecutive *kharif* seasons of 2012 and 2013 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, to evaluate the effect of cultivars and weed management practices on weed dynamics, yield attributes, yields and economics in zero-till direct-seeded rice (*Oryza sativa* L.). The dominant weed flora were *Echinochloa colona*, *Echinochloa crus-galli*, *Cynodon dactylon*, *Cyperus rotundus*, *Cyperus iria*, *Caesulia auxillaries* and *Eclipta alba*. Among rice cultivars, Arize-6129 had minimum weed density (425.9 and 480.1/m) and dry weight (76.7 and 86.4 g/m²), and maximum of grain yield (4.29 and 4.12 t/ha) during both the years, respectively. Among the weed management practices, application of bispyribac sodium + azimsulfuron (25 g +35 g/ha) + 0.25% NIS (post-emergence) at 15-20 DAS proved to be most effective in minimizing the weed density, weed dry weight and increased rice grain yield (4.33 and 4.16 t/ha, respectively). Arize-6129 produced maximum net returns (₹40402 and 37804/ha) and benefit: cost ratio (1.61 and 1.51) and economic efficiency (₹316 and 298/ha day), respectively during both the years. Among weed management practices, application of bispyribac sodium + azimsulfuron (25 g +35 g/ha) + NIS (0.25%) was the most economical and efficient.

Key words: Direct seeded rice, Economics, Herbicides, Weed control efficiency, ZT

Rice (*Oryza sativa* L.) is the most important human food crop of the world. Direct-seeded rice (DSR) is a cheaper alternative to transplanting but, heavy infestation of weeds is one of the major constrains for its successful cultivation (Upadhyay *et al.* 2016, Kumar *et al.* 2017). Dry seeding of rice can be sown under zero till (ZT) condition, thus saving fuel and labour cost due to reduction in cost of tillage and lesser wear and tear losses of machine (Bohra and Kumar 2015). Higher organic matter in ZT favours soil macro and micro-fauna build up and thus, maintain an open-pore structure of soil. ZT seeding results in saving in seed and fertilizer, reduction of soil erosion, improvement of soil physical and chemical properties and conservation of soil moisture, higher yields at lower production cost and reduction in global warming potential by 20-44% over ZT (Kumar *et al.* 2015a).

Weeds are emerging as most important cause of damage to DSR due to early crop-weed competition and lack of standing water for suppressing weed (Kumar *et al.* 2016a). Cultivars play an important role in crop-weed competition because of their diverse morphological traits, canopy structure and relative growth rate. A quick growing and early canopy cover enables a cultivar to compete better against weeds (Mishra *et al.* 2016). Traditional tall cultivars of rice exert effective smothering effect on weeds (Kumar *et al.* 2017). Rice cultivars with weed-suppressing characters are an important aspect to manage weeds in DSR (Kumar *et al.* 2016). Competitive ability of different rice varieties has become a focus of research; cultivar selection based on an ideal type has contributed remarkably to increased rice yield (Kumar *et al.* 2017). Cultivars with fewer tillers, lower panicle weights with thick roots and culms are suitable for DSR. Early heading rice varieties with better drought tolerance are better suited for DSR (Kumar *et al.* 2016). Further, it has been observed that early maturing rice cultivars and hybrids have smothering effect on weeds due to improved vigour and having the tendency of early canopy cover. Various herbicides have been used for controlling weeds under DSR (Kumar *et al.* 2017) but efficiency of chemical methods based on a single herbicide may be unsatisfactory, because of their narrow-spectrum of weed management (Kumar *et al.* 2017, Mishra and Kumar

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2017). Therefore, application of herbicides in combination or sequence can be more useful. Post-emergence application (20-25 DAS) of bispyribac sodium 25 g/ha is effective to manage diverse weed flora in DSR (Khaliq *et al.* 2011, Mishra *et al.* 2016). Azimsulfuron is introduced as post-emergence sulfonylurea herbicide useful for controlling weeds in rice (Mandal *et al.* 2011). Since, application of herbicides is more effective in managing weeds besides reducing the total energy requirement for rice, the present study was undertaken.

MATERIALS AND METHODS

Field experiment was conducted during the two consecutive *kharij* seasons of 2012 and 2013 at Agricultural Research Farm, Institute of Agricultural Sciences, BHU, Varanasi (25°18'N and 88°36'E, 128.93 m above mean sea level) in the Northern Gangetic alluvial plains. Total rainfall received during crop season was 691.2 and 818.3 mm during 2012 and 2013, respectively. Although distribution of rainfall was less in 1st year but they are uniform compared to 2nd year during the cropping period. Soil of experimental site was sandy clay loam in texture (sand: 45.77%, silt: 30.41%, clay: 23.82%) having 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). Experiment was laid out in a split plot design with four crop cultivars [Sarjoo 52, HUR 105, PAU-201 and Arize 6129] assigned in main-plot and six weed management practices [W₀- Weedy check, W₁- Weed free, W₂- Pendimethalin at 1.0 kg/ha (pre-em.), W₃- Pendimethalin at 1.0 kg/ha (pre-em.) *fb* bispyribac sodium at 25 g/ha + 0.25% NIS (post-em.), W₄-Oxadiargyl at 90 g/ha (pre-em.) *fb* bispyribac sodium at 25g/ha+0.25% NIS (post-em.), W₅-Bispyribac sodium+azimsulfuron (25 g+35 g/ha) + 0.25% NIS (post-em.) at 15-20 DAS] in sub-plots during both the years. Pre-sowing irrigation was given prior to sowing for better crop establishment. Sowing was done by Pant Nagar Zero-till drill machines keeping seeding rate of 30 kg/ha. Sowing was performed on 24 June 2012 and 25 June 2013, respectively during both years in presence of 40-45 cm residue retention. Recommended dose of fertilizer, i.e. 120 kg N + 60 kg P₂O₅ + 60 kg K₂O + 25 kg ZnSO₄/ha were applied uniformly to all the treatments through urea, di-ammonium phosphate (DAP), muriate of potash (MOP) and zinc sulphate (ZnSO₄) respectively. Half dose of N and full dose of P₂O₅, K₂O and ZnSO₄ were applied as basal and remaining half dose of N were applied as top dressing in two equal splits at active tillering and panicle initiation. Application of pre- and post-emergence herbicides was done with the help of a hand-operated knapsack sprayer fitted with flat-fan nozzle and water as a carrier at 600 l/ha as per treatment. Data on dry weight of weeds were recorded at 60 DAS by cutting weeds at ground level, washed with tap water, sun dried first followed oven drying at 70°C ± 2 for 48 hr and then weighed. Crop was threshed manually; grains were cleaned and weighed for expressing yield in t/ha. Economics was calculated on the basis of prevailing

market prices of inputs and produce. Net returns were calculated by deducting cost of cultivation from gross returns. Production efficiency and economic efficiency were computed as suggested by Kumawat *et al.* (2012). Data on weed density were recorded at 60 DAS and subjected to the square root transformation ($\sqrt{x+0.5}$) before statistical analysis to normalize their distribution. Data were analyzed statistically as per standard method (Panse and Sukhatme 1978). Test of significance of treatment differences were done on basis of t-test. Significant difference between treatments mean were compared with critical differences at 5% levels of probability.

RESULTS AND DISCUSSION

Effects on weeds

Altogether 22 weed species belonging to nine families were identified in the experimental field. *Echinochloa crus-galli*, *Echinochloa colona*, and *Cynodon dactylon* were major grasses, *Cyperus rotundus* and *Cyperus iria* as sedges and *Eclipta alba*, *Caesulia axillaries* as broad-leaved weeds (BLWs). Among weed flora, grassy weeds contributed maximum (%) followed by sedges (%) and BLWs (%). Susceptibility and tolerance of different types of seeds (crop and weeds) to herbicides depend upon their size, shape, structure, permeability and placement of seed in soil. Different crop cultivars showed marked difference on weed density (Table 1). Significantly higher weed density was recorded in PAU 201 followed by HUR 105, Sarjoo 52 and Arize 6129, respectively. Among cultivars, Arize 6129 registered significantly lower number of weeds and total dry matter accumulation. Population of sedges and BLWs in Arize 6129 were statistical similar with Sarjoo 52. Vigorous crop growth and droopy lower leaves of Arize 6129 was responsible for curtailing sunlight for profuse weed growth, which ultimately reduced weed infestation. Higher weed density obtained in PAU 201 might be due to fact that weeds under this cultivar had better weed seed emergence due to favourable soil environment and slow growth of crop and poor smothering efficiency (Kumar *et al.* 2016, Kumawat *et al.* 2018).

Weed density was significantly reduced in different weed management treatment compared to weedy check (Table 1). Amongst weed management methods, bispyribac sodium + azimsulfuron (25 g+35 g/ha) + 0.25% NIS (pre em.) at 15-20 DAS was most effective in reducing density of weeds. Plot treated with bispyribac Na+ azimsulfuron (25 g +35 g/ha) + 0.25% NIS (post-em.) at 15-20 DAS recorded less number of grasses, sedges and BLWS compared to other weed management methods during both the years. Higher efficacy of bispyribac sodium + azimsulfuron (25 g +35 g/ha) + 0.25% NIS (post-em.) at 15-20 DAS was due to effective control of both narrow and BLWs. These results are in close conformity with the findings of Khaliq *et al.* (2012).

In general, total weed dry weight increased up to 60 DAS and thereafter a decreasing trend was noticed

Table 1 Effect of cultivars and weed management on weed dynamics and weeds control efficiency and weed index of zero till direct seeded rice

Treatment	Total weed density (Number/m ²)		Total weed dry weight (g/m ²)		Weed control* efficiency (%)		Weed index (%)	
	2012	2013	2012	2013	2012	2013	2012	2013
<i>Cultivars</i>								
Sarjoo 52	20.2 (486.4)	21.3 (540.5)	8.6 (87.5)	9.1 (97.3)	43.2	41.4	24.7	24.9
HUR 105	21.3 (543.0)	22.4 (597.2)	9.1 (97.7)	9.6 (107.5)	36.6	35.2	28.1	28.1
PAU 201	22.8 (620.5)	23.8 (674.6)	9.8 (111.7)	10.2 (121.4)	27.6	26.8	37.2	37.4
Arize 6129	18.8 (425.9)	20.0 (480.1)	8.1 (76.7)	8.6 (86.4)	50.3	47.9	21.1	21.1
SEm±	0.08	0.09	0.03	0.04				
LSD (P=0.05)	0.28	0.29	0.12	0.12				
<i>Weed management practices</i>								
Weedy check	29.2 (856.7)	30.3 (921.7)	12.4 (154.2)	12.9 (165.9)	0.0	0.0	62.4	62.6
Weed free	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	100.0	100.0	0.0	0.0
Pendimethalin at 1.0 kg/ha	24.7 (611.1)	26.0 (676.1)	10.5 (110.0)	11.0 (121.7)	28.7	26.6	31.2	31.3
Pendimethalin at 1.0 kg/ ha <i>fb</i> bispriyibac at 25g/ ha + 0.25% NIS	23.6 (558.2)	24.9 (623.2)	10.0 (100.5)	10.6 (112.2)	34.8	32.4	24.4	24.5
Oxadiargyl at 90 g/ ha <i>fb</i> bispriyibac at 25g /ha + 0.25% NIS	24.0 (580.9)	25.4 (645.9)	10.2 (104.6)	10.8 (116.3)	32.2	29.9	28.2	28.5
Bispriyibac + azimsulfuron (25 g +35 g /ha) + 0.25% NIS at 15-20 DAS	22.4 (506.6)	23.8 (571.6)	9.5 (91.2)	10.1 (102.9)	40.9	38.0	20.3	20.4
SEm±	0.15	0.16	0.06	0.07				
LSD (P=0.05)	0.42	0.44	0.18	0.19				

*At 60 DAS; Population figures are transformed to $\sqrt{x+0.5}$ and actual figures are given in parenthesis

irrespective of different cultivars. It might be due to the fact that at later stages, growth of weeds ceased, resulted in reduced total weeds dry matter accumulation (Mishra *et al.* 2016). Similarly, weed dry weight was significantly influenced by crop cultivars at all the growth stages during both the years. Highest weed dry weight was recorded in PAU 201, which was higher over Arize 6129. Higher weed density resulted in significant increase of weed dry weight with PAU 201. Total weed dry weight was significantly reduced under bispriyibac sodium+ azimsulfuron (25 g +35 g/ha) + 0.25% NIS (post-em.) at 15-20 DAS compared to other weed management methods. It might be due to two-fold action of this combination that affected both grasses and BLWS. Poor performance of pendimethalin at 1 kg/ha applied alone was perhaps due to the fact that field was infected with complex weed flora and herbicides unable to manage grassy and BLWs. Kumar *et al.* (2016) also reported

that poor efficacy of herbicides in dry seeding was due to extended period of weed emergence as it provided better environment for coming out of weeds in diverse flushes.

Weed control efficiency and weed index (%)

Bispriyibac sodium+ azimsulfuron (25 g +35 g/ha) + 0.25% NIS (post-em.) at 15-20 DAS recorded the highest WCE, which was followed pendimethalin at 1.0 kg/ha (pre-em.) *fb* bispriyibac at 25g/ha + 0.25% NIS (POE) during both years (Table 1). Highest WCE was associated with bispriyibac + azimsulfuron (25 g +35 g/ha) + 0.25% NIS at 15-20 DAS, which may be attributed due to its effective control of complex weed flora of grasses, sedges and BLWs. Alone application of herbicides was recorded poor WCE as compared to sequential application due to control of only one group of weed flora, mainly grassy whereas sequential application of herbicides managed all

Table 2 Effect of cultivars and weed management on yield attributes and yields of zero till direct seeded rice

Treatment	Panicle/m row length (no.)		Panicle length (cm)		Grains/panicle (no.)		1000-grain weight (g)		Grain yield (t/ha)		Crop productivity (kg/ha/day)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Cultivars												
Sarjoo 52	49.9	47.0	23.1	22.3	101.6	96.7	23.9	23.4	4.1	3.9	32.0	30.9
HUR 105	46.9	44.0	22.2	21.1	97.6	92.7	23.3	22.7	3.9	3.8	30.6	29.6
PAU 201	42.9	39.9	20.1	19.1	88.6	83.1	22.4	21.8	3.4	3.3	26.7	25.8
Arize 6129	56.2	53.3	24.9	23.8	114.1	109.2	24.4	23.9	4.3	4.1	33.5	32.4
SEM±	1.2	0.9	0.4	0.4	1.6	1.6	0.3	0.3	0.1	0.1	-	-
LSD (P=0.05)	4.0	3.0	1.42	1.3	5.7	5.4	1.1	1.1	0.4	0.3	-	-
Weed management practices												
Weedy check	37.2	34.3	20.1	19.3	73.4	68.6	22.8	22.3	2.1	2.0	16.0	15.4
Weed free	57.5	54.6	24.9	23.8	121.1	116.2	24.3	23.7	5.4	5.2	42.5	41.2
Pendimethalin at 1.0 kg/ha	47.2	44.3	22.0	20.9	95.9	91.1	23.2	22.6	3.7	3.6	29.2	28.3
Pendimethalin at 1.0 kg/ha/bispyribac at 25g/ha + 0.25% NIS	50.7	47.8	22.8	21.7	100.7	95.8	23.4	22.9	4.1	3.9	32.1	31.0
Oxadiargyl at 90 g/ha/bispyribac at 25 g/ha + 0.25% NIS	47.8	44.8	21.5	20.5	95.0	89.3	23.3	22.7	3.9	3.7	30.6	29.5
Bispyribac + azimsulfuron (25 g +35 g/ha) + 0.25% NIS at 15-20 DAS	53.4	50.5	24.1	23.1	116.6	111.7	24.1	23.5	4.3	4.2	33.8	32.8
SEM±	0.9	0.8	0.4	0.3	1.5	1.5	0.3	0.2	0.1	0.1	-	-
LSD (P=0.05)	2.6	2.4	1.1	1.0	4.3	4.2	0.8	0.7	0.3	0.2	-	-

groups of weed flora (Kumar *et al.* 2017). Better control of weeds by pre-em. herbicides in early stages and control of later emerging weeds, sedges and BLWs by 2, 4-D was reported by Chinnusamy (2005).

Maximum weed index (WI) was associated with PAU 201 followed by HUR 105, Sarjoo 52 and Arize 6129, respectively during both the years (Table 1). Among weed control treatment, minimum WI was under bispyribac sodium + azimsulfuron (25 g+35 g/ha) + 0.25% NIS at followed by pendimethalin at 1.0 kg/ha/bispyribac at 25g/ha + 0.25% NIS during both the years. Whereas, maximum WI was recorded with sole application of pendimethalin at 1.0 kg/ha in 1st and 2nd year, respectively. Poor control of weeds with pre-em. herbicide may be attributed to its narrow-spectrum of weed control.

Yield attributes and yields

Significantly higher values of yield attributes were recorded with Arize 6129 followed by Sarjoo 52 and HUR 105 (Tables 2). Yield attributes of crop are function of growth and development that developed during vegetative phase of plant. Higher value of yield attributes under ZT-DSR with anchored residue are perhaps due to the better partitioning of photosynthates from source to sink as a result of better growth, which was obtained owing to favourable

growing condition in this seeding method. The result is in close proximity to those obtained by Kandasamy and Chinnusamy (2005).

All weed management methods significantly influenced yield attributes compared to weedy check. Amongst the various weed management method, bispyribac sodium+ azimsulfuron (25 g+35 g/ha) + 0.25% NIS at 20 DAS was significantly superior in panicles/m row, length of panicle, grains/panicle and 1000-grain weight (Table 2). Thus, results indicated that increase in yield contributing characters in bispyribac sodium + azimsulfuron (25 g+35 g/ha) + 0.25% NIS at 15-20 DAS was due to low weed growth, minimum weed competition during critical growth period. As a result these conditions enabled crop to make maximum use of inputs for crop growth, and thereby for formation and development of yield attributes. Kathirvelan and Vaiyapuri (2004) had reported that crop, which had minimum weed growth during critical period of crop growth had better growth and yield attributes.

Grain yield was significantly influenced by different cultivars during both the years (Table 2). Among the cultivars, Arize 6129 (4.3 and 4.1 t/ha) had recorded significantly higher grain yield over PAU 201 (3.4 and 3.3 t/ha) and HUR 105 (3.9 and 3.8 t/ha) but remained at par with Sarjoo 52 (4.1 and 3.9 t/ha) during both year. Arize

Table 3 Interaction effect of cultivars and weed management practices on grain yield of in zero till direct seeded rice

Treatment	Grain yield (t/ha)								
	Sarjoo 52		HUR 105		PAU 201		Arize 6129		
	2012	2013	2012	2013	2012	2013	2012	2013	
Weedy check	2.2	2.0	1.9	1.8	1.7	1.7	2.43	2.33	
Weed free	5.6	5.4	5.3	5.1	4.8	4.6	6.00	5.76	
Pendimethalin at 1.0 kg/ ha	3.9	3.7	3.7	3.6	3.3	3.2	4.05	3.88	
Pendimethalin at 1.0 kg ha <i>fb</i> bispyribac at 25g/ ha + NIS (0.25%)	4.3	4.1	4.2	4.0	3.6	3.4	4.42	4.24	
Oxadiargyl at 90 g/ ha <i>fb</i> bispyribac at 25 g/ ha + NIS (0.25%)	4.1	3.9	3.9	3.8	3.5	3.3	4.15	3.98	
Bispyribac + azimsulfuron (25 g +35 g /ha) + NIS (0.25%) at 15-20 DAS	4.6	4.4	4.5	4.3	3.6	3.4	4.71	4.52	
	<i>SEm</i> ±				<i>LSD</i> (<i>P</i> =0.05)				
			2012		2013		2012		2013
W at same level of C			0.2		0.16		0.5		0.4
C at same or different level of W			0.2		0.17		0.5		0.4

6129 had recorded 20.2 and 20.6% higher grain yield over PAU 201 in 1st and 2nd years, respectively. Increased grain yield of Arize 6129 was due to minimum weed density and more panicle bearing tillers, grains per panicle, panicle length and 1000-grain weight. Among the weed management methods, bispyribac sodium + azimsulfuron (25 g +35 g/ ha) + 0.25% NIS (post em.) at 15-20 DAS showed greater efficacy in increasing grain yield as comparison to other herbicides. This result can be attributed due to marked improvement in dry matter, yield attributes and better WCE.

Minimum grain yield was recorded in weedy check due to more weed growth and poor yield attributes of crops. Among cultivars, Arize 6129 had significantly maximum crop productivity of 33.5 and 32.4 kg/ha/day, respectively in both years. The lowest values of these attributes were recorded with Sarjoo 52 (32 and 30.9 kg/ha/day). This might be due to better yields (Kumar *et al.* 2016). Among the weed management practices, application of bispyribac sodium + azimsulfuron (25 g +35 g/ha) +NIS (0.25%) resulted in higher crop productivity (33.8 and 32.4 kg/ha/

Table 4 Effect of cultivars and weed management on economics of in zero till direct seeded rice

Treatment	Gross returns (₹/ha)		Net returns (₹/ha)		B:C ratio		Economic efficiency (₹/ha/day)	
	2012	2013	2012	2013	2012	2013	2012	2013
<i>Cultivars</i>								
Sarjoo 52	62953	60382	37752	35182	1.53	1.42	295	277
HUR 105	60116	57770	34615	32269	1.38	1.29	270	254
PAU 201	52521	50329	27081	24888	1.08	0.99	212	196
Arize 6129	65963	63365	40402	37804	1.61	1.51	316	298
<i>SEm</i> ±	1554	1223	1554	1223	0.06	0.06		
<i>LSD</i> (<i>P</i> =0.05)	5378	4232	5378	4232	0.21	0.19		
<i>Weed management practices</i>								
Weedy check	31386	30050	10602	9266	0.51	0.45	83	73
Weed free	83170	79952	44665	41447	1.26	1.17	349	326
Pendimethalin at 1.0 kg/ha	57576	55273	34905	32603	1.54	1.44	273	257
Pendimethalin at 1.0 kg/ha <i>fb</i> bispyribac at 25g/ ha + NIS (0.25%)	63339	60797	40237	37695	1.74	1.63	314	297
Oxadiargyl at 90 g/ha <i>fb</i> bispyribac at 25g/ ha + NIS (0.25%)	60118	57593	36516	33991	1.55	1.44	285	268
Bispyribac + azimsulfuron (25 g +35 g/ ha) + NIS (0.25%) at 15-20 DAS	66740	64101	42851	40212	1.79	1.68	335	317
<i>SEm</i> ±	1356	1167	1356	1167	0.05	0.06		
<i>LSD</i> (<i>P</i> =0.05)	3874	3336	3874	3336	0.16	0.16		

day), respectively in both the years. This might be due to the higher yields (Kumar *et al.* 2018).

Interaction effect

Interaction results revealed that Arize 6129 performed better in terms of grain yield when grown with application of bispyribac sodium+azimsulfuron (25 g + 35 g/ha) + NIS (0.25%) (Table 3). However, the lowest yields were associated with Sarjoo-52 with weedy check. This might be due to competitive ability of cultivar and higher efficacy to manage weed of respective herbicides (Kumar *et al.* 2017).

Economics

Cultivars and weed management practices markedly influenced economics during both the years (Table 4). Among cultivars, Arize 6129 performed significantly better in terms of gross returns (₹ 65963 and ₹ 63365/ha), net returns (₹ 40402 and ₹ 37804/h), and benefit: cost ratio (1.61 and 1.51) and economic efficiency (₹ 316 and 298/ha/day) over rest of treatments. The lowest values of these attributes were recorded with Sarjoo 52. This might be due to the better yield and net returns associated with respective treatment. Among the weed management practices, application of bispyribac sodium+ azimsulfuron (25 g+35 g/ha) +NIS (0.25%) was recorded significantly higher gross returns (₹ 66740 and ₹ 64101/ha), net returns (₹42851 and ₹ 40212/ha), benefit: cost ratio (1.79 and 1.68) and economic efficiency (₹ 335 and ₹ 316/ha/day) over rest of treatments.

It may be concluded that growing of Arize 6129 and weed control through bispyribac-sodium + azimsulfuron (25 g +35 g/ha) + 0.25% NIS (post-em.) was found better in order to achieve the maximum weed control efficiency, productivity and profitability under the middle Indo-Gangetic Plains of Eastern India.

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