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Short communication

Impact of different herbicides and their combinations on production economics of winter rice in West Bengal

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Rice is the life-blood of the Asia-Pacific Region where 56% of humanity lives, producing and consuming more than 90% of the world rice. Rice contributes 43% of total food grain production and 46% of the cereal production of India. Rice is the staple food of about 3.5 billion people and demand is expected to continue to grow as population increases (GRiSP 2013). Among different states of India, West Bengal is the leading state in rice production. During the year 2007-08, the average productivity of *Aus*, *Aman* and *Boro* was 2009 kg/ha, 2.31 t/ha and 3.26 t/ha, respectively and the state average of rice productivity was 2.57 t/ha (Samanta and Mallik 2004). Weeds are greatest constraint in rice crop and impose a serious negative effect on crop production and market value. On an average, farmers lose 37% of their rice yield to pests and diseases, and that these losses can range between 24% and 41% depending on the production situation (IRRI 2015). Herbicides are being widely looked as an alternatve of manual labour. Hence, different herbicides were tested to see their effect on economics of rice production.

The field experiment was conducted at the Instructional Farm of Bidhan Chandra Krishi Viswavidyalaya, new alluvial zone (NAZ) of West Bengal under the sub-tropical humid climate during *Kharif* Season (July to November) of 2015 on soil with medium fertility status, having sandy loam in texture (pH- 6.7). The experiment was laid out at randomized block design (RBD) having thirteen treatments, *viz.* butachlor 1.5 kg/ha (granules) as pre-emergence (PE) at 2 days after transplanting (DAT) with one hand weeding (40 DAT), pyrazosulfuron-ethyl 25 g/ha as PE (2 DAT) with one hand weeding (40 DAT), bensulfuron-methyl + pretilachlor 10 kg (granules)/ha as PE (2 DAT) with one hand weeding (40 DAT), bispyribac-sodium 10% SC 25 g/ha as post-emergence (POE) at 20 days after transplanting (DAT), metsulfuron-methyl + chlorimuron-ethyl 4 g/ha as POE (20 DAT), butachlor (PE - 2 DAT) + bispyribac-sodium (POE – 20 DAT), pyrazosulfuron-ethyl (PE - 2 DAT) + bispyribac-sodium (POE – 20 DAT), (bensulfuron-methyl + pretilachlor) as PE (2 DAT) + bispyribac-sodium (POE - 20 DAT), butachlor (PE - 2DAT) + (metsulfuron-methyl + chlorimuron-ethyl as POE (20 DAT)), pyrazosulfuron-ethyl (PE-2 DAT) + (metsulfuron-methyl + chlorimuron-ethyl as POE (20 DAT)), (bensulfuron-methyl 0.6% + pretilachlor as PE - 2 DAT) + (metsulfuron-methyl + chlorimuron-ethyl as POE (20 DAT)), two hand weeding at 20 and 40 DAT, weedy check, replicated thrice. Herbicides were sprayed using knapsack sprayer fitted with a flat fan nozzle at a spray volume of 500 l/ha except the granular herbicides, which were applied by mixing with sand 50 kg/ha. The variety '*Swarna (MTU-7029)*' was grown with recommended package of practices followed uniformly.

The observations on yield and yield attributes like grain yield, straw yield, no. of panicles/m^2, filled grains/panicle and 1000-seeds weight were recorded at harvest. Weed and crop biomass at different growth stages of rice, weed index and economics were worked out. All the collected data was analyzed statistically to the design RBD by following the procedure laid out by Gomez and Gomez (1984).

The observations revealed that the predominant weed species were *Cynodon dactylon*, *Leersia hexandra*, *Echinochloa colona*, *Commelina benghalensis*, *Brachiaria mutica*, *Echinochloa Crusgalli*, *Cyperus rotundus*, *Cyperus difformis*, *Fimbristylis dichotoma*, *Scirpus validus*, *Ammannia baccifera*, *Ageratum haustonianum*, *Spilanthus paniculata*, *Marsilea quadrifolia*, *Scoparia dulcis*, *Sphenoclea zeylenica*, *Xanthium strumarium*, *Ludwigia parviflora*, *Ipomoea reptens*, *Lindernia ciliata*, and *Nymphoides indica*.

Effect on rice biomass

Dry matter accumulation increased progressively from 30 to 60 DAT. But, variations were observed in different treatments. The better weed control made the availability of soil moisture,

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nutrients *etc*. to crop by reducing the crop-weed competition. Twice hand weeding at 20 and 40 DAT treatment resulted maximum biomass accumulation of rice crop followed by bensulfuron-methyl + pretilachlor 10 kg/ha as PE 2 DAT 1 HW 40 DAT and bensulfuron-methyl + pretilachlor as PE 2 DAT + bispyribac-sodium POE at 20 DAT. Reddy *et al*. (2012) reported that pre-emergence application of bensulfuron methyl + pretilachlor 75 + 750 g/ha at 5 DAT effectively controlled sedges, grasses and broad-leaf weeds (Table 1).

Effect on rice yield attributes

During the first year of the experiment, statistically significant differences were noticed between treated and untreated plots (Table 1). There were no significant differences among different treatments because it was a genetical character and thus was not affected by crop-weed competition or moisture and nutrients present into the soil.

Hand weeding twice at 20 and 40 DAT, bensulfuron-methyl + pretilachlor as PE with one hand weeding at 40 DAT, combined application of bensulfuron-methyl + pretilachlor as PE + bispyribac -sodium as POE gave more numbers of panicles/m^2 and filled grains/panicles (Table 1). Although the number of panicles was not much lesser in control (weedy check), yet it was significantly different from the treated plants.

Effect on rice yield

Highest rice straw and grain yield (5.80 and 4.53 t/ha) was recorded with hand weeding twice at 20 and 40 DAT, which gave significantly higher grain yield of transplanted rice over all the treatments tested followed by bensulfuron-methyl + pretilachlor 10 kg/ ha as PE at 2 DAT + 1 HW at 40 DAT (5.57 and 4.20 t/ha) and bensulfuron-methyl + pretilachlor as PE at 2 DAT + bispyribac-sodium POE at 20 DAT (5.53 and 4.17 t/ha). All the cultural and herbicidal treatments gave significantly higher grain yield than weedy check. Hand weeding twice (20 and 40 DAT) performed best and increased the grain yield, the straw yield and the biological yield by 42, 24 and 32%, respectively over weedy check. Herbicide combinations (bensulfuron-methyl + pretilachlor as PE + bispyribac-sodium as POE also showed a broad spectrum management of both annual and perennial weeds. Similar observation was also made by Teja *et al*. (2015).

Economics

The application of bensulfuron-methyl + pretilachlor 10 kg (G)/ha as PE and metsulfuron-methyl + chlorimuron-ethyl 4 g/ha as POE was the most cost saving and environmentally sound treatment followed by the application of PE (bensulfuron-methyl + pretilachlor) + POE (bispyribac-sodium). The maximum cost of cultivation was observed in hand weeding at 20 and 40 DAT compared to other treatments. Pre-emergence application of bensulfuron-methyl + pretilachlor 10 kg (G)/ha + one hand weeding at 40 DAT was also found to be effective in weed control. Similar results were also opined by Reshma *et al*. (2015). Among herbicidal treatments, the highest B: C

Table 1. Effect of weed control treatments on rice biomass and grain yield attributes

Treatment	Rice biomass (g/m^2)			Yield attributes		
	30 DAT	45 DAT	60 DAT	No. of panicles /m^2	No of filled grains /panicle	1000-seed weight (g)
Butachlor 1.5 kg/ha as PE at 2 DAT + 1 HW at 40 DAT	92.3	154.2	221.2	318.8	116.7	17.62
Pyrazosulfuron-ethyl 25 g/ha as PE at 2 DAT + 1 HW at 40 DAT	86.1	138.1	182.5	287.5	104.0	17.91
Bensulfuron-methyl + pretilachlor 10 kg/ha as PE at 2 DAT + 1 HW at 40 DAT	96.7	173.9	252.5	350.0	140.3	18.47
Bispyribac-sodium 25 g/ha as POE at 20 DAT	85.8	122.0	160.7	285.4	101.3	17.34
Metsulfuron-methyl + chlorimuron-ethyl 4 g/ha POE at 20 DAT	82.6	117.4	160.7	277.1	99.0	17.31
Butachlor 1.5 kg/ha (PE at 2 DAT) + bispyribac-sodium 25 g/ha (POE at 20 DAT)	77.6	109.6	150.2	245.8	83.7	17.31
Pyrazosulfuron-ethyl 25 g/ha (PE at 2 DAT) + bispyribac-sodium 25 g/ha (POE at 20 DAT)	90.5	145.8	194.8	310.4	114.3	17.66
Bensulfuron-methyl + pretilachlor 10 kg/ha (PE 2 DAT) + bispyribac-sodium 25 g/ha POE - 20 DAT	95.2	162.2	231.8	331.3	138.3	17.85
Butachlor 1.5 kg/ha (PE at 2 DAT) + metsulfuron-methyl + chlorimuron-ethyl 4 g/ha (POE 20 DAT)	80.0	113.1	155.7	264.6	91.7	17.32
Pyrazosulfuron-ethyl 25 g/ha (PE at 2 DAT) + metsulfuron-methyl + chlorimuron-ethyl 4 g/ha (POE at 20 DAT)	89.2	143.0	190.5	304.2	108.0	17.59
Bensulfuron-methyl + pretilachlor 10 kg/ha (PE 2DAT) + metsulfuron-methyl + chlorimuron-ethyl 4 g/ha (POE 20 DAT)	93.2	156.7	223.8	325.0	135.8	18.38
Two hand weeding at 20 and 40 DAT	99.5	192.1	279.2	370.8	153.0	18.41
Weedy check	74.2	104.3	135.5	225.0	77.0	16.59
LSD (P=0.05)	3.48	11.07	13.99	19.34	11.15	NS

PE - Pre-emergence; POE - Post-emergence; DAT - Days after transplanting; HW - Hand weeding

Table 2. Effect of weed control treatments on rice yield, weed index and economics of rice production

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Weed index (%)	Return from straw (x10^3 `)	Return from grain (x10^3 `)	Gross return (x10^3 `)	Cost of cultivation (x10^3 `)	Net return (x10^3 `)	B:C
Butachlor 1.5 kg/ha as PE at 2 DAT + 1 HW at 40 DAT	3.63	5.20	19.85	8.29	50.82	59.11	33.86	25.25	1.74
Pyrazosulfuron-ethyl 25 g/ha as PE at 2 DAT + 1 HW at 40 DAT	3.23	4.83	28.68	7.60	46.62	54.22	33.72	20.50	1.61
Bensulfuron-methyl + pretilachlor 10 kg/ha as PE at 2 DAT + 1 HW at 40 DAT	4.20	5.57	7.35	8.85	54.18	63.03	34.06	28.97	1.85
Bispyribac-sodium 25 g/ha as POE at 20 DAT	3.10	4.73	31.62	7.50	50.40	57.90	31.40	26.50	1.84
Metsulfuron-methyl + chlorimuron-ethyl 4 g/ha POE at 20 DAT	2.87	4.63	36.76	7.39	42.95	50.34	30.30	20.04	1.66
Butachlor 1.5 kg/ha (PE at 2 DAT) + bispyribac-sodium 25 g/ha (POE at 20 DAT)	2.33	4.47	48.53	7.15	38.22	45.37	32.50	12.87	1.40
Pyrazosulfuron-ethyl 25 g/ha (PE at 2 DAT) + bispyribac-sodium 25 g/ha (POE at 20 DAT)	3.53	5.17	22.06	7.95	49.42	57.37	32.36	25.01	1.77
Bensulfuron-methyl + pretilachlor 10 kg/ha (PE 2 DAT) + bispyribac-sodium 25 g/ha POE - 20 DAT	4.17	5.53	8.09	8.50	53.62	62.12	32.70	29.42	1.90
Butachlor 1.5 kg/ha (PE at 2 DAT) + metsulfuron-methyl + chlorimuron-ethyl 4 g/ha (POE 20 DAT)	2.67	4.53	41.18	7.24	43.82	51.06	31.39	19.67	1.63
Pyrazosulfuron-ethyl 25 g/ha (PE at 2 DAT) + metsulfuron-methyl + chlorimuron-ethyl 4 g/ha (POE at 20 DAT)	3.27	4.87	27.94	7.80	48.02	55.82	31.25	24.57	1.79
Bensulfuron-methyl + pretilachlor 10 kg/ha (PE 2DAT) + metsulfuron-methyl + chlorimuron-ethyl 4 g/ha (POE 20 DAT)	4.07	5.47	10.29	8.40	52.22	60.62	31.59	29.03	1.92
Two hand weeding at 20 and 40 DAT	4.53	5.80	-	9.19	58.80	67.99	36.73	18.92	1.85
Weedy check	2.23	4.30	50.74	6.94	33.60	40.54	28.81	11.74	1.41
LSD (P=0.05)	0.71	0.94	-	-	-	-	-	-	-

value (1.92) was obtained from the treatment bensulfuron-methyl + pretilachlor as PE at 2 DAT + metsulfuron-methyl + chlorimuron-ethyl as POE at 20 DAT followed by bensulfuron-methyl + pretilachlor as PE at 2 DAT + bispyribac-sodium POE at 20 DAT treatment (1.90). Singh *et al.* (2007) also reported that metsulfuron-methyl 8 g/ha provided higher profitable returns and B: C which corroborated the present findings. Bensulfuron-methyl + pretilachlor 10 kg/ha as PE at 2 DAT + 1 HW at 40 DAT and bispyribac-sodium 25 g/ha as POE at 20 DAT also resulted higher B: C values that were 1.85 and 1.84 respectively compared to other treatments. In case of hand weeding twice at 20 and 40 DAT treatment, B: C value was 1.85.

This study indicated that use of herbicides in combination may profitably replace the time consuming and expensive hand weeding for weed control in transplanted winter rice. So, the application of bensulfuron-methyl + pretilachlor as pre-emergence (PE) with bispyribac-sodium as post-emergence (POE) was more superior over hand weeding twice (20 and 40 DAT).

SUMMARY

Hand weeding twice at 20 and 40 days after transplanting (DAT) gave best results in reducing both weed density and biomass and ultimately increased the grain (4.53 t/ha) and straw yield (5.80 t/ha). Next highest grain (4.20 t/ha) and straw yield (5.57 t/ha) was obtained with bensulfuron-methyl + pretilachlor (granules) 10 kg/ha as pre-emergence + one hand weeding at 40 DAT treatment followed by combined herbicidal treatment bensulfuron-methyl + pretilachlor (granules) 10 kg/ha as PE + bispyribac-sodium 25 g/ha as post emergent gave grain yield 4.17 t/ha and straw yield 5.53 t/ha. Considering the benefit: cost ratio, the highest value (1.92) was obtained with the performance of bensulfuron-methyl + pretilachlor as PE + metsulfuron-methyl + chlorimuron-ethyl as POE.

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