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Research Paper

Yield and economics of drum-seeded rice (*Oryza sativa*) as influenced by broad-spectrum herbicides and herbicide mixtures

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ABSTRACT

A study was conducted during the summer season of 2015 and 2016 at, Gerua, with 10 weed-control practices, to evaluate the efficacy of different broad-spectrum herbicides and their combinations on performance of drum-seeded rice (*Oryza sativa* L.) in lowland ecosystem of Lower Brahmaputra Valley Zone of Asom. Results of the experiment revealed that *Cyperus difformis* L., *Schoenoplectiella juncoides* (Roxb.) Lye; syn, *Scirpus juncoides* Roxb. among sedges; *Echinochloa crus-galli* (L.) P. Beaur.; E. *glabrescens, Leptochloa chinensis* Kossenko (L.) Nees, among grasses; and *Anagallis arvensis* L. among broad-leaf weeds were dominant in drum-seeded rice. The composition of grasses, sedges and broad-leaf weeds in weedy check at 60 days after sowing (DAS) was 15.1, 71.5 and 13.4% respectively. Crop-weed competition throughout the crop-growth period caused 37.4% grain yield loss. Mechanical weeding by paddy weeder at 20 DAS followed by manual weeding at 40 DAS registered 9.2% lower grain yield than manual weeding twice. Weed-free condition by repeated manual weeding recorded the highest cost of cultivation of ₹45,000/ha, whereas bensulfuron-methyl + pretilachlor (60 + 600 g/ha) at 10 DAS resulted in the lowest cost of cultivation (₹36,000/ha). Though higher grain yield of 5.82 t/ha was recorded in weed-free plots, it did not record higher benefit: cost (B: C) ratio. Bensulfuron-methyl + pretilachlor (60 + 600 g/ha) at 10 DAS recorded the highest B : C ratio (2.28) followed by flucetosulfuron (25 g/ha) at 20 DAS (2.24).

Key words **:** Broad-spectrum herbicides, Drum-seeded rice, Economics, Herbicide combinations, Yield

Rice being the principal food crop of Asom, is grown in about 2.64 million ha area under different ecologies and seasons. Drum seeding is very simple to use and quite effective in sustaining the production of rice. It offers benefits like reduction in labour requirement due to elimination of nursery preparation and makes rice cultivation more profitable and gives higher benefit: cost ratio (Bharadwaj *et al.,* 2018).

The major problem in drum-seeded rice is the crop-weed competition which results in reduction of grain yield up to 64.4% (Sangeeta *et al*., 2009). Manual weeding is the common practice to control weeds, but it is tedious, costly and not at all cost-effective. On the contrary, herbicides are low priced, easy to apply and ensure timely weed control in rice. Some of the herbicides are very specific to a particular group of weeds. Several pre- and post- emergence herbicides have been proved to provide a good degree of weed control in drum-seeded rice as reported by many researchers. Pre- emergence herbicides like pendimethalin, pretilachlor, butachlor, pyrazosulfuron ethyl were found effective for suppression of early flashes of weeds, but most of them are very narrow spectrum, their application window is also only 1–3 days after sowing (DAS) and failed to control the subsequent flashes of weeds that appeared at later stages of crop growth (Das *et al.,* 2012). In this context, post- emergence herbicides, viz. azimsulfuron, bispyribac sodium, bensulfuron-methyl, flucetosulfuron, are found promising for broad-spectrum weed control either alone or in different combinations in drum-seeded rice fields. Repeated use of same herbicides in the same crop in the same field may lead to shifting of weed flora and occurrence of herbicide-resistant weeds which may be avoided by the use of herbicide mixtures and rotations of different mode of action. Phyto-toxicity and environmental consequences advocated the use of low-dose broad-spectrum herbicides and their mixtures to provide weed control in direct-seeded rice for higher productivity and profit. Therefore, the study was conducted to evaluate the efficacy of different broad-spectrum herbicides and their combinations

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on performance of drum-seeded rice in lowland ecosystem of Lower Brahmaputra Valley Zone of Asom.

MATERIALS AND METHODS

The field experiment was carried out during the summer season of 2015 and 2016 at Regional Rainfed Lowland Rice Research Station Gerua, (26^o 14' 59'' N, 90^o 33' 44'' E and at 49 m above sea-level), Asom. The region comes under Lower Brahmaputra Valley Agro climatic zone of Asom and characterized as humid subtropical monsoon type climate with annual average rainfall of 1,500 mm. The agro-ecological zone receives a substantial amount of pre-monsoon rainfall (20–30%) during March to May. The total pre- monsoon rainfall during the crop growing season in 2015 was 852.5 mm, whereas it was 725.3 mm in 2016. So, these amounts of rainfall were useful to grow summer rice in the region with little initial supplemental irrigation for establishment of the crop. The meteorological weekly average maximum and minimum temperature from the last week of January to first week of June was 24.4°C to 33.4°C and 8.0°C to 16.1°C respectively. The experimental field was sandy clay loam in texture (25% clay, 15% silt, 60% sand), bulk density 1.32 g/cm^3, having *p*H 5.6 (using 1 : 2.5, soil : water suspension), organic carbon 0.90%, available nitrogen 270 kg/ha, phosphorus 15.5 kg/ha and potassium 220.3 kg/ha.

The treatments consisted of azimsulfuron (35 g/ha) at 20 DAS, flucetosulfuron (25 g/ha) at 20 DAS, bispyribac sodium (30 g/ha) at 20 DAS, bensulfuron-methyl + pretilachlor (60 + 600 g/ha) at 10 DAS, azimsulfuron + bispyribac sodium (22 + 25 g/ha) at 20 DAS, flucetosulfuron (25 g/ha) at 5 DAS followed by (fb) bispyribac sodium (25 g/ha) at 20 DAS, manual weeding twice (20 and 40 DAS), mechanical weeding by paddy weeder at 20 DAS fb manual weeding at 40 DAS, weed-free check and weedy check, were replicated thrice in a randomized block design.

Seeds of the rice variety 'Naveen' were soaked in plain water mixed with bavistin @ 1 g/kg seed for 2 days. After draining out the water the seeds were packed in gunny bags and covered with paddy straw and kept for 48 hours for sprouting. Pre-germinated seeds were sown by using 12-row-drum seeders at 20 cm × 10 cm on puddled saturated soil. For initial 10 days moisture level of the soil was maintained at saturation for proper establishment of the seedlings. Thinning and gap-filling was done at 15 DAS. A fertilizer dose of 80-40-40 kg N-P-K/ha was applied in 3 split doses. Weed-control treatments were imposed in the experimental plots as per the schedule of treatments. All the herbicides except the granular one were applied at saturated soil moisture as per the protocol using knapsack sprayer fitted with flat fan nozzle at spray volume of 350 litres/ha. The ready-mix granular herbicide bensulfuron-methyl + pretilachlor (60 + 600 g/ha) was mixed with dry sand at 10 kg/ha and uniformly broadcast in the field. In weed-free plots, weeds were removed by manual weeding at 15, 30, 45 and 60 DAS.

A quadrat of 50 cm × 50 cm (0.25 m^2) placed randomly at 4 places in the sampling area of each plot at 45 and 60 DAS and weeds present within the quadrat were counted. Counting of grasses, broad-leaf weeds and sedges were taken separately and their sum was used to obtain total weed density (no/m^2). Weeds were uprooted from the area under each quadrat placed in each plot and labelled properly. After a thorough cleaningm weeds were dried in a hot-air oven at 70°C till constant weights were recorded. Samples were kept in desiccators for cooling in dehumidified condition and their dry matter (biomass) was recorded.

Weed-control efficiency (WCE) was computed using weed density data by following formula.

$$\text{WCE (\%)} = \frac{WDW_C - WDW_T}{WDW_C} \times 100$$

where WCE, Weed-control efficiency (%); WDW_C, weed density in weedy check plot, and WDW_T, weed density in treated plot.

weed-control index (WCI) was calculated as:

$$\text{Weed-control index (\%)} = \frac{WDM_C - WDM_T}{WDM_C} \times 100$$

where, WCI, Weed-control index (%); WDM_C, weed dry weight (aerial parts) in weedy check plot; and WDM_T, weed dry weight (aerial parts) in treated plot.

Weed-persistence index (WPI) was calculated by using the formula:

$$\text{WPI} = \frac{\text{Weed density in weedy check}}{\text{Weed density in treated plot}} \times \frac{\text{Weed dry weight in treated plot}}{\text{Weed dry weight weedy check}}$$

Herbicide-efficiency index (HEI) was computed as:

$$\text{HEI} = \frac{(Y_T - Y_C) \times 100}{Y_C} \Big/ \frac{WDM_T \times 100}{WDM_C}$$

where Y_T and Y_C stand for the yields of treated and control respectively, while WDM_T and WDM_C are weed dry-matter in treated and control respectively.

Crop-resistance index (CRI) was computed by using the formula

$$\text{CRI} = \frac{\text{Rice biomass in treated plot} \times}{\text{Rice biomass in weedy check}} \frac{\text{Weed biomass weedy check}}{\text{Weed biomass in treated plot}}$$

Weed index (WI) was determined as:

$$\text{WI (\%)} = \frac{Y_{WFC} - Y_T}{Y_{WFC}} \times 100$$

where WI, weed-index (%); Y_{WFC}, Yield of the crop in weed-free plot; Y_T, yield of the crop in plot under weed-control treatment.

The crop was harvested at maturity when about 85% of the grains became straw- or golden yellow coloured. From middle portion of each plot 6 m^2 areas were separately harvested and bundled. After proper drying, threshing was done by using pedal thresher. The grains were cleaned by winnowing and sun-dried to a moisture content of 14%. Simultaneously, paddy straws were also properly sun-dried. After proper drying, plot-wise weight of grains and straws were recorded separately. Plant height, panicles/m^2, grains/ panicle, 1,000-grain weight were recorded at the harvest time of harvesting by following the standard procedure from the pre- determined 12 hills per each plot. Economics of drum-seeded rice under different treatments were computed by taking the prevailing local market price. The data were analysed in Ms-Excel for randomized block design RBD and the results were presented. The critical difference (CD) values are calculated to compare the treatments.

RESULTS AND DISCUSSION

Weed flora and their relative density

Rice sown through drum seeder on puddled soil is associated with the problem of prolific growth of weeds and infestation of diverse weed flora (Rhaghavendra *et al*., 2015). The results of this experiment revealed that, 14 species of weeds belonging to 8 families infested the rice crop. Among the different categories of weeds, sedges were dominant (71.47%), followed by grasses (15.11%) followed by broad-leaf weeds (13.42%). Continuous stagnation of water due to occurrence of rain after seedling emergence and subsequent crop growth stages favoured sedges to dominate.

Echinochloa cruss-galli; E. glabrescens and *Leptochloa chinensis* among grasses, *Cyperus difformis* and *Scirpus juncoides* among sedges, and *Lindernia anagallis* among broadleaved weeds were dominant in the experimental field. Overall, the relative density of most prevalence weeds *Cyperus difformis, Schoenoplectiella juncoides;* Syn. *Scirpus juncoides* and *Lindernia anagallis* were 40.24, 26.33 and 7.49% respectively. The dominance of *C. difformis* and *C. iria* in drum-seeded rice were reported by many workers (Raghavendra *et al*. 2015; Parthipan, 2016). Continuous submergence of rice field encourages the emergence of sedge weed *Schoenoplectiella juncoides* in drum-seeded rice. Singh *et al*. (2014, 2017) reported the infestation of *S. juncoides* in summer rice. Parthipan (2016) also observed *Leptochloa chinensis* in puddled drum-seeded rice. In our study, the probable reason of dominance of *Cyperus difformis* and *Schoenoplectiella juncoides* was due to continuous stagnation of water after the establishment of seedlings and the emergence of second flush of *Lindernia anagallis* in later stage of crop growth showed higher relative density.

Weed density and biomass

Crop-weed competition throughout the growth period in the weedy check plots resulted significantly higher weed density and biomass at 45 and 60 DAS (Table 1). This is due to undisturbed weed growth in weedy check. All the weed-control treatments resulted in significant reduction in weed density and biomass compared with the weedy check. Among the herbicidal treatments, flucetosulfuron (25 g/ha) at 5 DAS followed by bispyribac sodium (25 g/ha) at 20 DAS resulted in the lowest weed density and biomass at 45 DAS and it was at par with the other herbicide treatments. Weed control by paddy weeder at 20 DAS followed by manual weeding at 40 DAS recorded higher weed density and biomass at 45 DAS than the herbicidal treatments. The higher weed density and biomass was due to the presence of a good number of weeds near to the rice hills.

Weed indices

All the herbicidal treatments registered more than 90 and 88% weed-control efficiency weed-control index (WCE) and WCI, respectively, and comparable with that of manual weeding twice (Table 1). The weed-persistence index (WPI) indicates the resistance in weeds against the tested treatments and confirms the effectiveness of the selected herbicides. Among the herbicidal treatments flucetosulfuron (25 g/ha) at 20 DAS recorded lowest WPI and closely followed by bensulfuron-methyl + pretilachlor (60 + 600 g/ha) at 10 DAS which was comparable with hand-weeding twice. The crop-resistance index (CRI) indicates the relationship between a proportionate increase in crop biomass and a proportionate decrease in weed biomass in the treated plots. The manual weeding recorded higher CRI (28.8) followed by bensulfuron-methyl + pretilachlor (60+ 600 g/ha) at 10 DAS (Table 1).

The weed index (WI) gives the extent of crop loss due to weed competition in rice and it varies with weed-control practices (Table 1). The yield loss was higher under weedy check (WI ~ 37.4%). Among the herbicide treatments, azimsulfuron + bispyribac sodium recorded lowest weed index (5.5%) which was closely followed by other herbicide treatments (Table 1).

All the herbicidal treatments registered lower weed index, weed-persistence index and higher WCE and WCI and these were comparable with manual weeding twice. The increase in the grain yield in weed- control treatments was owing to less weed density, weed biomass, WPI with higher weed-control efficiency (Ahmed and Chauhan,

Table 1. Effect of weed-control practices on weed population, biomass and weed indices of drum-seeded rice (mean data of 2 years)

Treatment	Weed Population (no/m²)		Weed biomass (g/ m²)		Weed indices at 45 DAS					
	45 DAS	60 DAS	45 DAS	60 DAS	WCE	WCI	WPI	CRI	HEI	WI
Azimsulfuron (35 g /ha) at 20 DAS	4.5 (19.7)	4.2(17.0)	2.51 (8.7)	4.6(20.9)	96.0	91.1	2.3	15.3	5.5	7.6
Flucetosulfuron (25 g/ha) at 20 DAS	4.5 (19.4)	5.2 (27.0)	3.32 (11.5)	5.4(28.7)	93.8	88.1	1.7	13.6	5.0	7.0
Bispyribac sodium (30 g/ha) at 20 DAS	4.9 (23.5)	4.1 (16.0)	3.29 (11.1)	4.3(17.9)	96.4	89.2	3.0	12.6	4.7	7.3
Bensulfuron-methyl + pretilachlor (60+ 600 g/ha) at 10 DAS	4.6 (20.5)	3.9 (14.4)	3.06 (9.3)	4.0(15.7)	96.1	93.3	1.8	21.4	8.5	6.9
Azimsulfuron+bispyribac sodium (22+25 g/ha) at 20 DAS	4.2 (17.4)	3.8 (13.9)	2.93 (8.4)	2.8(7.4)	97.2	92.9	2.6	19.1	7.3	5.5
Flucetosulfuron (25 g/ha) at 5 DAS fb bispyribac sodium (25 g/ha) at 20 DAS	3.4 (11.3)	3.8 (14.0)	2.69 (7.1)	3.9(14.9)	96.3	93.8	1.8	19.8	9.1	8.6
Manual weeding twice (20 and 40 DAS)	6.4 (40.7)	6.4 (40.9)	2.41 (5.7)	4.0(15.3)	92.5	93.9	0.8	28.8	9.3	3.2
Paddy weeder at 20 DAS fb manual weeding at 40 DAS	8.4 (69.5)	8.7 (74.9)	4.31 (19.3)	5.4(28.2)	86.0	85.9	1.1	8.9	3.1	10.5
Weed-free	0.7 (0.0)	0.7 (0.0)	0.70 (0.0)	0.70(0.0)	100.0	100.0	0.0	–	–	0.0
Weedy-check	20.7 (426.0)	21.7 (469.3)	10.29 (118.1)	14.36(219.0)	0.0	0.0	–	1.0	–	37.4
SEm±	0.74	0.84	0.46	0.42	–	–	–	–	–	–
CD (P=0.05)	2.3	2.58	1.44	1.35	–	–	–	–	–	–

Figures in parentheses are the original values. The data were transformed through square-root ($\sqrt{x+0.5}$) method before analysis

DAS, Days after sowing; WCE, weed-control efficiency; WCI, weed-control index; WPI, weed-persistance index; CRI, crop-resistance index; HEI, herbicide-efficiency index; WI, weed index

2014). This confirms that weed is a crucial yield-limiting factor in drum-seeded rice and weed control should be properly addressed to make direct-seeded rice cultivation sustainable as well as profitable.

Yield and yield attributes

Weed control at critical period of crop growth is the one of the important aftercare practices to achieve potential yield of rice. In the present study, weed-free condition recorded higher grain yield but it was at par with manual weeding twice (Table 2). The higher grain yield in weed-free plot was mainly due to the lower weed dry weight, higher weed-control efficiency, higher panicles/m² and higher grains/panicle (Table 2). In weed-free environment, rice plants are able to absorb more nutrients, thus, resulting in higher growth, yield attributes and yield (Raghvendra *et al*., 2015).

The lowest grain yield was observed under weedy check. The weed-free plot and the plots treated with manual weeding twice revealed 59.5 and 54.5% increase in grain yield over the weedy check, whereas mechanical weeding at 20 DAS followed by manual weeding at 40 DAS recorded reduction in the grain yield of 12.0 and 9.2% as compared to weed-free and manual weeding twice respectively. The reduction in grain yield in mechanical weeding at 20 DAS followed by manual weeding at 40 DAS was due to ineffectiveness of paddy weeder to control the weeds present in close to rice hills at early stage of crop growth.

All herbicide treatments showed rice grain yield at par with the manual weeding twice. Tank-mix application of azimsulfuron + bispyribac sodium (22 + 25 g/ha) at 20 DAS did not record any significant increase in grain yield over its single-shot application. Single-shot application of bispyribac sodium as pre-emergent found effective in increasing enhancing of rice was also reported by Teja *et al*. (2015). Similarly, the Saha *et al*. (2016) reported effectiveness of sole application of azimsulfuron for managing composite weed flora as well as enhancing yield of rice under different culture.

Sequential application of flucetosulfuron (25 g/ha) at 5 DAS fb bispyribac sodium (25 g/ha) at 20 DAS did not record any gain in enhancing rice yield as compared to sole application of flucetosulfuron (25 g/ha) at 20 DAS. This might be due to toxic effect of flucetosulfuron on wet direct-seeded rice when applied at 5 DAS (data not presented). Ali *et al*. (2018) reported the efficacy of flucetosulfuron in term of reduction of weeds biomass and increase in rice grain yield of transplanted rice.

Economics

The highest cost of cultivation was incurred in weed-

Table 2. Effect of weed-control practices on yield attributes, yield and economics of drum seeder rice (mean data of 2 years)

Treatment	Panicles (no./m²)	Grains/ panicle	1,000-grain weight (g)	Grain yield (t/ha) 2015	2016	Mean	Straw yield (t/ha)	Cost of cultivation (×10³ ₹/ha)	Gross returns (×10³ ₹/ha)	Net returns (×10³ ₹/ha)	Benefit: cost ratio
Azimsulfuron (35 g /ha) at 20 DAS	374.0	89.2	21.7	5.51	5.25	5.38	7.11	36.7	81.3	44.6	2.22
Flucetosulfuron (25 g/ha) at 20 DAS	383.5	88.0	21.4	5.62	5.22	5.42	7.04	36.5	81.8	45.3	2.24
Bispyribac sodium (30 g/ha) at 20 DAS	361.0	88.0	21.6	5.55	5.25	5.40	7.11	37.3	81.6	44.3	2.19
Bensulfuron-methyl + pretilachlor (60+ 600 g/ha) at 10 DAS	378.5	89.4	21.8	5.67	5.18	5.43	6.97	36.0	81.9	45.9	2.28
Azimsulfuron+bispyribac sodium (22+25 g/ha) at 20 DAS	387.9	91.9	21.6	5.65	5.35	5.50	6.93	38.4	83.0	44.6	2.16
Flucetosulfuron (25 g/ha) at 5 DAS fb bispyribac sodium (25 g /ha) at 20 DAS	366.5	88.1	21.1	5.38	5.27	5.33	7.22	39.6	80.6	41.0	2.04
Manual weeding twice (20 and 40 DAS)	389.0	95.3	21.1	5.74	5.54	5.64	7.06	41.6	85.1	43.5	2.05
Paddy weeder at 20 DAS fb manual weeding at 40 DAS	353.5	85.4	21.6	5.47	4.96	5.22	6.96	38.5	78.9	40.4	2.05
Weed-free	398.7	99.3	21.5	5.90	5.74	5.82	7.15	45.0	87.8	42.8	1.95
Weedy-check	283.9	71.8	21.0	4.18	3.13	3.65	5.60	32.8	55.5	22.7	1.69
SEm±	12.5	2.86	0.24	0.13	0.13	0.13	0.19	–	12.8	12.8	0.04
CD (P=0.05)	37.15	9.76	NS	0.39	0.37	0.35	0.55	–	38.4	38.43	0.11

DAS, Days after sowing

free treatments, followed by manual weeding twice (Table 2). The higher cost of production was due to high cost of human labour involved for weeding. Replacement of manual weeding at 20 DAS with mechanical weeding by paddy weeder reduced the cost of production by 8.1% compared to the manual weeding twice. Similarly, all the herbicidal treatments recorded less cost of cultivation than the manual weeding twice. Among the herbicidal treatments, bensulfuron-methyl + pretilachlor (60 + 600 g/ha) at 10 DAS incurred less cost of cultivation, followed by flucetosulfuron (25 g/ha) at 20 DAS.

All weed-control practices recorded significantly higher gross and net return than the weedy check. This is owing increase in grain and straw yield in weed-controlled plot as compared to weedy check. Although weed-free condition recorded highest gross return, but it does not reflect in net return due to high production cost incurred in repeated manual weeding. All the herbicidal treatments registered net return at par with the manual weeding twice. Benefit: cost ratio (B : C) is a better economic index as compared to gross return in terms of economic efficiency of any weed control practices. Higher grain yield in weed-free plot did not record higher B : C ratio due to higher cost of production (Sureshkumar and Durairaj, 2018). Weedy check registered lower B : C ratio due to severe reduction in grain and straw yield resulted in low gross return. All the herbicidal treatments except the treatment flucetosulfuron (25 g/ha) at 5 DAS followed by (fb) bispyribac sodium (25 g/ha) at 20 DAS record higher B : C ratio as compared to manual weeding. Shulatana *et al*. (2016) also reported higher benefit: cost ratio in herbicide-based weed management. Bensulfuron-methyl + pretilachlor (60 + 600 g/ha) at 10 DAS recorded highest B : C ratio (2.28), followed by flucetosulfuron (25 g/ha) alone at 20 DAS (2.24).

Tank-mix application of azimsulfuron + bispyribac sodium (22 + 25 g/ha) at 20 DAS did not record any significant gain in B : C ratio over its single-shot application due to no significant difference in grain yield under 2 treatments. Application of flucetosulfuron (25 g/ha) alone at 20 DAS resulted in higher B: C ratio than sequential application of flucetosulfuron (25 g/ha) at 5 DAS fb bispyribac sodium (25 g /ha) at 20 DAS and it was at par with manual weeding. Ali *et al.* (2018) also observed higher B: C ratio in the plot treated with flucetosulfuron in rice.

From this study, it may be concluded that ready-mix post-emergent herbicides bensulfuron-methyl + pretilachlor (60 + 600 g/ha) at 10 DAS and flucetosulfuron (25 g/ha) at 20 DAS were found effective in broad-spectrum weed control and increase in the grain yield of drum-seeded summer rice in Lower Brahmaputra Valley agro climatic zone of Assam.

REFERENCES

Ahmed, S. and Chauhan, B.S. 2014. Performance of different herbicides in dry seeded rice in Bangladesh. *The Scientific World Journal,* ID729418.14 pages, accessed on 10.08.2018 in http:P//dx.doi.org/10.1153/2014/279468.

Ali, M.N., Prerna, Sah, A., Kumari, G., Izhar, T., Alam, P. and Lakra, R.K. 2018. Influence of herbicides on growth and profitability of transplanted rice (*Oryza sativa* L.) in Jharkhand. *Journal of Pharmacognosy and Phytochemistry* SP1: 401–404.

Bhardwaj, R., Singh, M.K., Singh, C.S. and Singh, A.K. 2018. Efficacy of crop establishment methods on yield and economics of rice under puddled condition. *International Journal of Current Microbiology and Applied Science* (Special issue 7)**:** 3,635–3,631.

Das, T.K., Tuti, M.D., Sharma, R., Paul, T. and Mirjha, P.R. 2012. Weed management research in India: An overview. *Indian Journal of Agronomy* **57**(3rd IAC Special issue): 148–156.

Parthipan, T. 2016. Strategies for weed management in drum seeded rice under puddle condition (*Oryza sativa* L.). *International Journal of Forestry and Crop Improvement* **7**(1): 14–18.

Ravisankar, N., Chandrsekaran, B., Raja, R., Din, M., and Chaudhuri, S.G. 2008. Influence of integrated weed management practices on productivity and profitability of wet seeded rice (*Oryza sativa*). *Indian Journal of Agronomy* **53**(1): 57–61.

Raghavendra, B.M., Susheela, R., Praveen Rao, V. and Madhavi, M. 2015. Efficacy of different weed management practices on growth and yield of direct wet seeded rice sown through drum seeder. *The Bioscan* **10**(1): 97–101.

Saha, S., Munda, S. and Adak, T. 2016. Efficacy of azimsulfuron against complex weed flora in transplanted rice (*Oryza sativa*) under rainfed shallow lowland. *Indian Journal of Agricultural Sciences* **86**(2): 186–191.

Sangeetha, S.P., Balakrishnan, S.P.A.R and Maheswari, J. 2009. Influence of seeding methods and weed management practices on direct seeded rice. *Indian Journal of Weed Science* **41**(3 and 4): 210–212.

Satapathy, B.S., Pun, K.B., Singh, T. and Rautaray, S.K. 2016. Influence of dates of sowing and varieties on growth and yield of direct wet sown early *ahu* rice (*Oryza sativa* L.) under flood prone lowland ecosystem of Assam. *Annals of Agricultural Research New series* **37**(1): 1–5.

Singh, T., Satapathy, B.S., Gautam, P., Lal, B., Kumar, U., Saikia, K. and Pun, K.B. 2017. Comparative efficacy of herbicides in weed control and enhancement of productivity and profitability of rice. *Experimental Agriculture* doi: 10.1017/S0014479717000047, pp. 1–19.

Singh, T., Satapathy, B.S, Pun, K.B. and Lenka, S. 2014. Evaluation of pre-emergence herbicides and hand weeding on weed control efficiency and performance of transplanted early *ahu* (*boro*) rice. *Journal of Agricultural Technology* **1**(1): 52–56.

Shultana, R., Biswas, J.C., Mamun, M.A.A. and Nahar, L. 2016. Fertilizer and weed management options for direct wet seeded rice in dry season. *Bangladesh Rice Journal* **20**(1): 65–75.

Sureshkumar, R. and Durairaj, S.N. 2018. Labour-saving weed management practices in transplanted rice. *International Journal of Chemical Studies* **6**(2): 590–593.

Teja, K.C., Duary, B., Kumar, M. and Bhowmic, M.K. 2015. Effect of bensulfuron-methyl + pretilachlor and other herbicides on mixed weed flora of wet season transplanted rice. *International Journal of Agriculture, Environment and Biotechnology* **8**(2): 323–329.