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Yield and economics of direct seeded rice as influenced by nitrogen and weed management practices

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Abstract
A field experiment was conducted at Agricultural Research Farm, Institute of Agricultural sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, during rainy (kharif) season of 2015 and 2016 to study the effect of nitrogen and weed management in direct seeded rice (*Oryza sativa* L.) under irrigated condition. The experiment comprised of 24 treatments including all the combinations of 4 nitrogen and 6 weed management treatments. The results indicated that the maximum filled spikelets, fertility percentage, yield, gross returns, net returns and B: C ratio were recorded under nitrogen application of ¼ N basal + ¼ N at active tillering stage + ¼ N at panicle initiation stage + ¼ N at heading stage which was statistically at par with 1/3 N at basal + 1/3 N at active tillering stage + 1/3 N at panicle initiation stage and significantly higher than remaining nitrogen treatments. The minimum filled spikelets, fertility percentage, yield, gross returns, net returns and B:C ratio were recorded under nitrogen application of ½ N basal + ¼ N at active tillering stage + ¼ N at panicle initiation stage. Among weed management practices, significantly the maximum filled spikelets, fertility percentage, yield, gross returns, net returns and B:C ratio were recorded under application of bispyribac at 25 g a.i. ha^{-1} + azimsulfuron at 17.5 g a.i. ha^{-1} + NIS (0.25 %) at 15-20 DAS was significantly superior over other treatments.

Keywords: Direct-seeded rice, nitrogen, weed management, fertility, yield, economics

Introduction
Direct seeding of rice in the Indo-Gangetic plains has begun and farmers are finding the new technology attractive. The productivity of the DSR was on a par with transplanting and the net profit was higher. In spite of the weed menace, farmers in eastern U.P. and Bihar opt for dry-DSR when it is difficult for them to complete rice transplanting in time or water supplies are uncontrolled such as low or upland rice ecologies (Singh *et al*., 2010) [12]. Nitrogen is a key nutrient in determining the level of crop productivity. The efficiency of applied nitrogen is very low and varies from 20 to 25% in upland rice crop due to the oxidized condition prevailing in uplands and concomitant heavy nitrogen loss through percolating water. Hence, fractional application of nitrogen in right amount and proportion, and when it is needed the most seems to be a practical proposition. Weed is one of the major constraints for low productivity of upland rice (Angiras, 2002) [2]. In direct-seeded upland rice, weeds pose serious competition to the crop in early stage and cause heavy reduction in rice yield. Uncontrolled weeds reduce the yield up to 80% in direct-seeded upland rice. Weed control also facilitates higher absorption of applied nutrient, thus increases the efficiency of fertilizers application to the crops (Amarjit *et al.*, 2006) [1]. Manual and mechanical methods are not effective in controlling sedges and broad-leaved weeds in direct-seeded rice because of the high labour cost, scarcity of labour during the critical period of weed competition and unfavorable weather at weeding time. Hence usage of herbicides is becoming increasingly popular as a viable alternative to hand weeding. To avoid undesirable weed shift and herbicide resistance in weeds, the continuous use of herbicides with similar mode of action has to be restricted. But in spite of the usage of all such herbicidal combinations, control failures, lot of escapes or regeneration in some of the weed species have been recently noticed in DSR at many locations. Therefore, considering the emergence of diverse weed types in rainy (kharif) season, the purpose cannot be solved by one-time application of herbicide alone. Considering these problems, we have to apply several herbicides in combination or in sequence, other than the already used combinations, which can provide more useful solution in controlling complex and diverse weed flora in DSR (Raj *et al*. 2013) [9].

Material and Methods

A field experiment was conducted during rainy (kharif) season of 2015 and 2016 at Agricultural Research Farm, Department of Agronomy, Institute of Agricultural sciences, Banaras Hindu University, Varanasi, Uttar Pradesh. The soil was Gangetic alluvial having Sandy clay loam in texture with pH 7.60. It was moderately fertile, being low in available organic carbon (0.40%), available N (198.38 $kgha^{-1}$), and medium in available P (17.78 kg ha^{-1}) and K (216.32 kg ha^{-1}). The experiment was laid out in split-plot design with three replications. The nitrogen management subjected to main plots while weed management in sub plots. A combination of 24 treatments consisting of 4 nitrogen management, viz. N_1 - ½ N basal + ¼ N at active tillering stage + ¼ N at panicle initiation stage, N_2 - ¼ N at basal + ½ N at active tillering stage + ¼ N at panicle initiation stage, N_3 - 1/3 N at basal + 1/3 N at active tillering stage + 1/3 N at panicle initiation stage and N_4 - ¼ N basal + ¼ N at active tillering stage + ¼ N at panicle initiation stage + ¼ N at heading stage and 6 weed management treatments, viz. W_0 - Weedy check, W_1- Two hand weedings at 20 and 40 DAS, W_2 - Pendimethalin 1.0 kg a.i ha^{-1} (PE) fb Bispyribac at 25 g a.i ha^{-1} + NIS (0.25%) at 15-20 DAS, W_3 - Bispyribac at 25 g a.i. ha^{-1} + Pyrazosulfuron at 20 g a.i. ha^{-1} + NIS (0.25%) at 15-20 DAS, W_4 - Oxadiargyl at 90 g a.i. ha^{-1} (PE) *fb* Bispyribac at 25g a.i. ha^{-1} + NIS (0.25%) at 15-20 DAS and W_5 - Bispyribac at 25 g a.i. ha^{-1} + Azimsulfuron at 17.5 g a.i. ha^{-1}) + NIS (0.25 %) at 15-20 DAS. A uniform dose of 150 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} were applied in all the plots. Full dose of phosphorus and potash were applied as basal application and nitrogen was applied as treatment wise. 'HUR 105' variety of rice @ 35 kg ha^{-1} was used for seeding of rice. The required quantity of pre-emergence and post-emergence herbicides was sprayed as per treatment using spray volume of 600 litres of water ha^{-1} with the help of knap sack sprayer fitted with flat fan nozzle. Grain yield and its attributes were also recorded during the course of investigation. The cost of cultivation and returns were calculated by taking in to account the prevailing cast inputs and minimum support price of output. The data recorded on various parameters of rice crop were analyzed following standard statistical analysis of variance procedure.

Results and Discussion

Eighteen weed species, which belong to six families, were identified in the experimental field during both the years of field investigation. Among these, seven species viz., *Echinocloa crusgalli*, *Echinocloa Colona*, *Eleusine indica*, *Cynodon dactylon*, *Leptochloa chinensis Digitaria sanguinalis* and *Dactyloctenium aegypticum* were grasses; three species viz., *Cyperus rotundus*, *Cyperus iria* and *Fimbristylis miliacea* were sedges; and the remaining eight species viz., *Eclipta alba*, *Caesulia axillaris*, *Ammania baccifera*, *Phyllanthus niruri*, *Commelina benghalensis*, *Euphorbia hirta*, *Ludwigia parviflora* and *Spilanthus acmella* were broad leaved weeds.

Effect on yield attributes

All the yield attributes of *viz.*, number of spikelets $panicle^{-1}$, number of filled spikelets $panicle^{-1}$, fertility % and test weight (1000-grain weight) were significantly influenced by different nitrogen and weed management practices.

Thus, the nitrogen application of¼ N at basal + ¼ N at active tillering stage + ¼ N at panicle initiation stage +¼ N at heading stage and 1/3 N at basal + 1/3 N at active tillering stage + 1/3 N at panicle initiation stage produced significantly higher number of spikelets $panicle^{-1}$, total number of filled spikelets, maximum fertility % and test weight than other nitrogen treatments. It might be due the resultant of lower total weed infestation and maximum crop dry matter accumulation. As a result these treatments had minimum competition from weeds and consequently improved the crop growth and partitioning of photosynthates from source to sink. Similar results were observed by Singh *et al*. (2015) [13]. Mahajan *et al.* (2011) [7] reported that increasing panicle number per unit area and high filled grains per panicle are important determinant of sink size and DSR crop due to better translocation of assimilates to panicle during anthesis can result in high fertile florets and kernel yield.

All the weed management treatments significantly influenced the yield attributes as compared to weedy check. Hand weeding twice at 20 and 40 DAS and the application of bispyribac at 25 g a.i. ha^{-1} + azimsulfuron at 17.5 g a.i. ha^{-1} + NIS (0.25 %) at 15-20 DAS recorded significantly higher yield attributes than the other treatments. This could be due to higher weed control efficiency and lowest weed index in these treatments, which showed that it had very little or not much more crop-weed competition for different growth factors of production thus consequently led to enhanced growth and development of rice. The maximum yield attributes were recorded under two hand weedings at 20 and 40 DAS was also reported by Nayak *et al*. (2014) [8]. The maximum yield attributes were reported with bispyribac at 25 g a.i. ha^{-1} + azimsulfuron at 17.5 g a.i. ha^{-1} + NIS (0.25 %) at 15-20 DAS was reported by Ghosh *et al*. (2017) [5].

Effect on Grain and Straw Yield (Kg Ha^{-1})

Grain yield is an ultimate result of yield attributes *viz*. total number of spikelets $panicle^{-1}$, fertility percentage and 1000 grain weight. The various nitrogen treatments and weed management practices were significantly affected grain and straw yield of crop during both the years of experimentation. Harvest index was non-significant. Application of ¼ N at basal + ¼ N at active tillering stage + ¼ N at panicle initiation stage +¼ N at heading stage recorded maximum grain and straw yield followed by 1/3 N at basal + 1/3 N at active tillering stage + 1/3 N at panicle initiation stage than other nitrogen treatments and was at par with each other. The increased grain and straw yield was perhaps the result of reduced weed population the improvement of yield attributes like number of grains per panicle and 1000-grain weight. These findings were in conformity with the results of Kumawat *et al*. (2017) [6]. The minimum grain and straw yield was recorded with nitrogen application of ¼ N at basal + ½ at N active tillering stage + ¼ N at panicle initiation stage and ½ N at basal + ¼ at N active tillering stage + ¼ N at panicle initiation stage due to higher weed infestation and its dry weight, low weed control efficiency and minimum yield attributes.

Amongst various weed management treatments, hand weeding twice at 20 and 40 DAS and the application of bispyribac at 25 g a.i. ha^{-1} + azimsulfuron at 17.5 g a.i. ha^{-1} + NIS (0.25 %) at 15-20 DAS resulted in significantly higher grain and straw yields than other weed management treatments. The increased yield in these treatments might be due to cumulative effect of lower weed population, increased number of filled grains per panicle and test weight. The minimum grain yield was recorded under weedy check which was attributed due to maximum weed population, weed dry weight and poor yield attributing characters. The maximum grain and straw yield was recorded under two hand weedings as reported by Ramesh *et al*. (2015) and the maximum grain and straw yield was recorded under bispyribac at 25 g a.i. ha^{-1} + azimsulfuron at 17.5 g a.i. ha^{-1} + NIS (0.25 %) at 15-20 DAS as given by Ghosh *et al*. (2017) [5]. The minimum grain and straw yields were recorded under weedy check due to more weed infestation and their dry matter accumulation and lower yield attributing characters. These results are in accordance with the findings of Ganai *et al*. (2014) [4].

Effect on Economics

The real comparison of different treatments can only judged on the basis of their economic viability. The gross return obtained by yield of crop varied markedly due to different treatments, which ultimately influenced the net return and benefit: cost ratio. The economics of different nitrogen treatments revealed that the maximum gross return, net return and benefit: cost ratio were recorded with nitrogen application of ¼ N at active tillering stage + ¼ N at panicle initiation stage + ¼ N at heading stage and 1/3 N at basal + 1/3 N at active tillering stage + 1/3 N at panicle initiation stage than remaining nitrogen treatments in both the years of experimentation. This is mainly due to higher yield attributes and grain yield. Lowest gross return, net return and benefit: cost ratio was recorded with ½ N at basal + ¼ at N active tillering stage + ¼ N at panicle initiation stage due to reduced grain yield. Similar results have been given by Singh *et al*. (2015) [13].

Economic evaluations of various weed management practices revealed that the maximum gross return, net return and benefit:cost ratio were recorded with the application of bispyribac at 25 g a.i. ha^{-1} + azimsulfuron at 17.5 g a.i. ha^{-1} + NIS (0.25 %) at 15-20 DAS followed by bispyribac at 25 g a.i. ha^{-1} + pyrazosulfuron at 20 g a.i. ha^{-1} + NIS (0.25%) at 15-20 DAS than other weed management treatments. This could be attributed to higher grain yield of rice. The similar findings were given by Bajiya *et al*. (2016) [3]. The miniimum gross return, net return and benefit: cost ratio were recorded under weedy check which might be due to lowest yield of rice. Similar findings were given by Saravanane *et al*. (2016) [11].

Conclusion

Application of ¼ N at basal + ¼ N at active tillering stage + ¼ N at panicle initiation stage +¼ N at heading stage was found most economical in DSR as it gave maximum net return and B:C ratio. Among weed management treatments, application of bispyribac at 25 g a.i. ha^{-1} + azimsulfuron at 17.5 g a.i. ha^{-1} + NIS (0.25 %) at 15-20 DAS gave maximum net return and B: C ratio than hand weeding twice at 20 and 40 DAS. In direct seeded rice tank mix application of herbicides were most economical when compared to hand weeding.

Table 1: Effect of nitrogen management and weed management practices on yield attributes of direct seeded rice

Treatments	Total spikelets/ panicle		Total filled spikelets		Fertility %		1000 grain weight (g)	
	2015	2016	2015	2016	2015	2016	2015	2016
Nitrogen management								
N_1- ½ N at basal + ¼ Nat active tillering stage + ¼ N at panicle initiation stage	112.67	105.89	94.35	85.13	82.68	79.41	23.77	23.10
N_2- ¼ N at basal + ½ N at active tillering stage + ¼ N at panicle initiation stage	105.95	99.57	84.89	76.65	78.93	75.56	22.90	22.23
N_3- 1/3 N at basal + 1/3 N at active tillering stage + 1/3 N at panicle initiation stage	118.73	113.37	102.10	94.69	85.26	82.67	24.43	23.76
N_4- ¼ N at basal + ¼ N at active tillering stage + ¼ N at panicle initiation stage +¼ N at heading stage	121.87	117.13	106.02	99.39	86.78	84.63	24.90	24.24
SEm±	1.96	1.83	1.60	2.29	1.29	1.63	0.31	0.29
CD (P=0.05)	6.77	6.33	5.54	7.91	4.48	5.64	1.08	1.00
Weed management practices								
W_0 - Weedy check	86.19	80.41	61.93	55.31	70.87	67.68	22.25	21.68
W_1- Two hand weedings at 20 and 40 DAS	129.25	122.44	113.65	105.00	88.65	86.30	24.77	24.02
W_2 - Pendimethalin at 1.0 kg a.i. ha^{-1} (PE) fb Bispyribac at 25 g a.i. ha^{-1} + NIS (0.25%) at 15-20 DAS	115.95	110.01	98.29	90.02	84.75	81.61	23.79	23.11
W_3 - Bispyribac at 25 g a.i. ha^{-1} + Pyrazosulfuron at 20 g a.i. ha^{-1} + NIS (0.25%) at 15-20 DAS	121.08	117.03	104.55	97.85	86.14	83.34	23.94	23.28
W_4- Oxadiargyl at 90 g a.i. ha^{-1} (PE) *fb* Bispyribac at 25g a.i. ha^{-1} + NIS (0.25%) at 15-20 DAS	111.33	104.83	92.66	83.76	83.02	79.74	23.66	23.01
W_5- Bispyribac at 25 g a.i. ha^{-1} + Azimsulfuron at 17.5 g a.i. ha^{-1}) + NIS (0.25 %) at 15-20 DAS	125.03	119.23	108.98	101.16	87.04	84.73	24.58	23.81
SEm±	1.99	1.95	1.95	1.77	1.32	1.36	0.26	0.25
CD (P=0.05)	5.70	5.58	5.57	5.07	3.78	3.87	0.75	0.71

Table 2: Effect of nitrogen management and weed management practices on yield and harvest index of direct seeded rice

Treatments	Grain yield (Kg ha^{-1})	Straw yield (Kg ha^{-1})			Harvest index (%)	
	2015	2016	2015	2015	2016	2015
Nitrogen management						
N_1- ½ N at basal + ¼ Nat active tillering stage + ¼ N at panicle initiation stage	3841.15	3496.08	5694.99	5436.41	39.55	38.42
N_2- ¼ N at basal + ½ N at active tillering stage + ¼ N at panicle initiation stage	3651.17	3316.48	5528.28	5250.15	39.30	38.15
N_3- 1/3 N at basal + 1/3 N at active tillering stage + 1/3 N at panicle initiation stage	3988.33	3633.83	6031.28	5743.81	39.92	38.54
N_4- ¼ N at basal + ¼ N at active tillering stage + ¼ N at panicle initiation stage +¼ N at heading stage	4091.89	3783.53	6135.50	5869.02	40.03	38.81
SEm±	87.15	90.75	118.58	119.71	0.50	0.61

CD (P=0.05)	301.59	314.05	410.33	414.25	NS	NS
Weed management practices						
W_0 - Weedy check	1965.00	1698.50	3315.92	2993.48	37.33	35.26
W_1- Two hand weedings at 20 and 40 DAS	4766.75	4380.50	6904.08	6610.00	40.84	39.84
W_2 - Pendimethalin at 1.0 kg a.i. ha^{-1} (PE) fb Bispyribac at 25 g a.i. ha^{-1} + NIS (0.25%) at 15-20 DAS	4036.75	3723.88	6149.92	5928.50	39.75	38.68
W_3 - Bispyribac at 25 g a.i. ha^{-1} + Pyrazosulfuron at 20 g a.i. ha^{-1} + NIS (0.25%) at 15-20 DAS	4364.56	4008.30	6508.33	6206.05	40.14	39.24
W_4- Oxadiargyl at 90 g a.i. ha^{-1} (PE) *fb* Bispyribac at 25g a.i. ha^{-1} + NIS (0.25%) at 15-20 DAS	3665.75	3323.45	5828.25	5536.99	38.53	37.38
W_5- Bispyribac at 25 g a.i. ha^{-1} + Azimsulfuron at 17.5 g a.i. ha^{-1}) + NIS (0.25 %) at 15-20 DAS	4560.00	4210.25	6718.58	6404.08	40.48	39.67
SEm±	123.66	147.97	160.48	157.20	1.05	1.18
CD (P=0.05)	353.43	422.93	458.68	449.31	NS	NS

Table 3: Effect of nitrogen management and weed management practices on economics of direct seeded rice

Treatments	**Cost of cultivation (Rs ha^{-1})**	**Gross returns (Rs ha^{-1})**	**Net returns (Rs ha^{-1})**				**B:C ratio**	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Nitrogen management								
N_1- ½ N at basal + ¼ Nat active tillering stage + ¼ N at panicle initiation stage	35814.19	35814.19	60351.48	54875.82	24537.29	16876.71	1.67	1.52
N_2- ¼ N at basal + ½ N at active tillering stage + ¼ N at panicle initiation stage	35814.19	35814.19	57453.24	52114.84	21639.05	14110.44	1.59	1.44
N_3- 1/3 N at basal + 1/3 N at active tillering stage + 1/3 N at panicle initiation stage	35814.19	35814.19	62753.32	57118.49	26939.13	19375.66	1.74	1.58
N_4- ¼ N at basal + ¼ N at active tillering stage + ¼ N at panicle initiation stage +¼ N at heading stage	36014.19	36014.19	64680.67	59397.53	28666.48	21327.32	1.78	1.63
Weed management practices								
W_0 - Weedy check	32042.98	32042.98	31176.29	27041.99	-866.69	-5000.99	0.97	0.84
W_1- Two hand weedings at 20 and 40 DAS	41042.98	41042.98	74772.61	68912.80	33729.63	27869.82	1.82	1.68
W_2 - Pendimethalin at 1.0 kg a.i. ha^{-1} (PE) fb Bispyribac at 25 g a.i. ha^{-1} + NIS (0.25%) at 15-20 DAS	36271.48	36271.48	63548.99	58815.07	27277.51	22543.59	1.75	1.62
W_3 - Bispyribac at 25 g a.i. ha^{-1} + Pyrazosulfuron at 20 g a.i. ha^{-1} + NIS (0.25%) at 15-20 DAS	34872.98	34872.98	68603.80	63175.70	33730.80	28302.71	1.97	1.81
W_4- Oxadiargyl at 90 g a.i. ha^{-1} (PE) *fb* Bispyribac at 25g a.i. ha^{-1} + NIS (0.25%) at 15-20 DAS	35144.23	35144.23	57891.14	52675.04	22746.91	17530.81	1.65	1.50
W_5- Bispyribac at 25 g a.i. ha^{-1} + Azimsulfuron at 17.5 g a.i. ha^{-1}) + NIS (0.25 %) at 15-20 DAS	35810.48	35810.48	71614.93	66272.71	35804.45	30462.22	2.00	1.85

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