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Research Paper

Yield and economics as influenced by nitrogen scheduling, weed management and rice establishment methods in transplanted rice (*Oryza sativa*)

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 2010 and 2011 at Varanasi, Uttar Pradesh, to evaluate the effect of nitrogen scheduling, rice–establishment methods and weed management on 'BPT 5204' rice (*Oryza sativa* L.) cultivar. The major group of weed species observed in the experimental field were grasses followed by broad-leaf weeds and sedges. Significant reduction in weed biomass was recorded in puddled transplanting as compared to unpuddled transplanting and in butachlor 1.50 kg/ha followed by cono-weeding at 20 days after transplanting (DAT) amongst the weed-management treatments. However, in the nitrogen scheduling treatments, significantly lesser weed biomass was recorded in initial reduced dose and delayed nitrogen application (one-fourth at 10 days, half at tillering stage and one-fourth at panicle-initiation stage) than conventional scheduling of nitrogen application (half at basal, one-fourth at tillering stage and one-fourth at panicle-initiation stage). Puddled transplanting resulted in significantly more grains/panicle, panicle length, panicles/hill, grain yield (t/ha), nitrogen uptake and nitrogen-use efficiency, net returns and benefit: cost ratio than unpuddled transplanting and in butachlor 1.5 kg/ha followed by cono-weeding at 20 DAT as compared to the other weed-management treatments. An initial reduced dose and delayed nitrogen application (one-fourth at 10 DAT, half at tillering stage and one-fourth at panicle-initiation stage) recorded significantly higher values of yield attributes, yields, net return and benefit: cost ratio than conventional scheduling of nitrogen application.

Key words : Nitrogen scheduling, Rice establishment methods, Weed management

In India, rice is generally grown by transplanting in puddled soils. Puddling buries weeds in the lower layer of the slurry, where they decompose by anaerobic action to form ammonium compounds which are retained much better than nitrate in the soil and can be used directly by the crop. Other reasons include good crop establishment, incorporation of fertilizers and crop residue into the soil, while in the case of wetland rice culture, it favours reduction of water permeability of soils. Since crop establishment in transplanting system is most input-intensive process, more efficient alternatives are urgently needed. In unpuddled transplanting, the field preparation is done without standing water. The field is prepared by summer ploughing followed by 1 or 2 harrowing at the time of transplanting and planking. The major advantage for this method may be lesser water requirement than puddled transplanted situation. However, under puddled situation, if water management is satisfactory, the weed menace is relatively lesser than unpuddled transplanting.

Weed control has always been a major factor in rice production throughout monsoonal Asia. Effective weed control often requires a combination of cultural, mechanical and chemical control measures, such as an integrated weed-management approach to delay herbicide resistance and reduce the herbicide load on the agro-ecosystem (Rao *et al.,* 2007). Singh *et al.* (2005) conducted an experiment with rice establishment and weed-management treatments at Pantnagar, and reported that the maximum reduction in weed population was obtained with the application of herbicides as pre-emergence supplemented with 2 hand-weedings at 30 and 60 days after sowing or transplanting (DAT) under all rice-establishment methods. Nitrogen is essential macronutrient for rice growth, and its application in an effective way for exploiting the maximum yield potential of modern rice cultivars is very important (Lui and Lu, 2005). The key to both improving efficiency of fertilizer use and reducing nitrogen losses is the synchronization of nitrogen supply from soil with plant demand of nitrogen. Nitrogen supply commonly limits grain yield in irrigated rice system. Application of adequate quantity at right stage of the crop synchronizing well with periods of

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most efficient utilization influence the growth, development and yield of rice on one hand, and reduce the cost of cultivation on the other. Devi *et al.* (2012) reported that one-fourth N as basal + one-fourth N at the active tillering stage + one-fourth N at the panicle initiation stage + one-fourth N at the heading stage and one-fourth N as basal + one-fourth N at the active tillering stage + one-fourth N at the panicle-initiation stage + one-fourth N at the flowering stage resulted in the highest grain and straw yields. Keeping above findings in view, the present field experiment was conducted to assess the yield and economics in transplanted rice as influenced by nitrogen scheduling, weed management and rice- establishment methods.

MATERIALS AND METHODS

A field experiment was conducted during the rainy seasons of 2010 and 2011 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (25° 18' N and 88° 36' E, 128.93 m from mean sea-level) in Northern Gangetic alluvial plains. Normally the period for the onset of monsoon is the third week of June and it lasts up to the end of September or sometimes extends up to the first week of October. The area also experiences some winter shower due to western disturbances during December to February. The soil was clay loam, deep, flat, well-drained, and chemical analysis of the experimental field before start of experiment revealed slightly basic soil reaction (*p*H=7.32) and low in organic carbon (0.48%) and available nitrogen (197.5 kg/ha), medium in available phosphorus (23.0 kg/ha) and available potassium (230.9 kg/ha).

The experiment was carried out in split-plot design, replicated thrice. The combination of 2 rice-establishment methods (puddled and unpuddled transplanting) and 5 weed-management treatments (butachlor 1.5 kg/ha followed by azimsulfuron 35 g/ha at 25 days after transplanting (DAT), pretilachlor 0.75 kg/ha followed by azimsulfuron 35 g/ha at 25 DAT, butachlor 1.5 kg/ha followed by cono-weeding at 20 DAT, 2 hand-weedings at 20 and 40 DAT and weedy) were allocated in main plot and 2 subplot treatments were conventional scheduling of nitrogen application (half at basal dressing, one-fourth at tillering stage and one-fourth at panicle-initiation stage) and initial reduced dose and delayed nitrogen application (one-fourth at 10 days, half at tillering stage and one-fourth at panicle-initiation stage) with the cultivar 'BPT 5204'. Treatment-wise pre-and post-emergence herbicides were applied by knap-sack sprayer fitted with flat-fan nozzle using 300 litres of water/ha.

The rice cultivar 'BPT 5204' is a medium-long-duration which was transplanted in July and harvested in November. To achieve the seedbed the land was prepared by giving 2 ploughings each followed by planking with the help of a tractor-drawn cultivator. The puddling followed by planking was done a day before of transplanting. In unpuddled transplanting the water was given after ploughing followed by planking before onset of monsoon. Weeds and stubbles of previous crops were removed, and at the time of transplanting, irrigation was applied to facilitate transplanting. Two seedlings/hill were transplanted at 20 cm × 15 cm spacing in experimental field. A fertilizer dose of 120, 60 and 60 kg N, P_2O_5 and K_2O/ha in the form of urea, single superphosphate and muriate of potash was applied to each experimental unit. Full dose of phosphorus and potassium were applied basal to rice crop before transplanting. A uniform dose of nitrogen in form of urea was applied as per the nitrogen-scheduling treatment. Weed dry weight was recorded at 60 days stage with the help of a quadrate (0.5 m × 0.5 m) placed randomly at 2 spots in each plot. The data on weed dry weight were subjected to square-root ($\sqrt{X+1}$) transformation before statistical analysis to normalize their distribution (Panse and Sukhatme, 1978). The crop was harvested at full physiological maturity, sun-dried for a week and threshed manually. All the biometrical observation on crop and weeds were observed as per the standard practices. Economics of different treatments were calculated taking into prevailing minimum support prices of inputs used and output obtained from each treatment. Total rainfall of 715.8 mm and 1,137.7 mm was received during rice crop seasons of 2010 and 2011 respectively.

RESULTS AND DISCUSSION

Weeds and their biomass (g/m²)

The major weed flora infesting the crop field was grassy weeds which included *Echinochloa colonum (*L.) Link, *Echinochloa crusgalli* (L.) P Beauv., *Cynodon dactylon* (L.) Pers., *Panicum repens* L. and *Paspalum distichum* L., whereas among broad-leaved weeds, *Ammania baccifera* (L.) Roxb., *Eclipta alba* (L.) Hask, *Caesulia axillaris* (L.) Roxb, *Commelina benghalensis* L., *Euphorbia hirta* L. and *Ludwigia parviflora* L. were predominant weeds and concerning sedges included *Cyperus iria* L., *Cyperus difformis* L. and *Fimbristylis miliaceae* L. Vahl during both the years. Significantly lesser weed biomass (Table 1) was recorded in puddled transplanting than unpuddled transplanting at 60 days and at harvesting. Amongst the weed-control treatments, the minimum weed biomass was recorded in butachlor 1.5 kg/ha followed by cono-weeding at 20 days and it was found significantly superior in reducing the weed biomass to pretilachlor 0.75 kg/ha followed by azimsulfuron 35 g/ha at 15 days and butachlor 1.5 kg/ha followed by azimsulfuron 35 g/ha at 25 days at both the stages of observations. Pretilachlor

0.75 kg/ha followed by azimsulfuron 35 g/ha at 15 days resulted in significantly lesser weed biomass than butachlor 1.5 kg/ha followed by azimsulfuron 35 g/ha at 25 days. Two hand-weeding recorded the minimum weed biomass as compared to all the weed-management treatments. However, all the weed-management treatments were significantly superior to weedy check in reducing the weed biomass. Initial reduced dose and delayed nitrogen application (one-fourth at 10 days, half at tillering stage and one-fourth at panicle-initiation stage) significantly reduced weed biomass compared to conventional scheduling of nitrogen application (half at basal dressing, one-fourth at tillering stage and one-fourth at panicle initiation stage). These results might be due to effective weed control resulting in lower weed density in the respective weed-management treatments. The results confirm the findings of Tiwari *et al.* (2013).

Interaction effect of weed management and nitrogen scheduling on weed biomass at 60 days (Table 2) was found significant. Data pertaining to interaction effect showed that butachlor 1.5 kg/ha followed by cono-weeding at 20 days + initial reduced dose and delayed nitrogen application (one-fourth at 10 days, half at tillering stage and one-fourth at panicle-initiation stage) and conventional scheduling of nitrogen application (half at basal dressing, one-fourth at tillering stage and one-fourth at panicle-initiation stage) was significantly superior in reducing weed biomass in comparison to rest of the weed-management and nitrogen-scheduling treatment combinations and both these treatments combinations were at par with each other.

Yield attributes of crop

Puddled transplanting resulted in significantly more grains/panicle, panicle length, panicles/hill (Table 1) than unpuddled transplanting. Higher values of yield attributes in puddled transplanting were perhaps owing to better partitioning of photosynthates from source to sink as a result of lower crop-weed competition. Similar findings were also reported by Singh *et al.* (2006). However, the differences in 1,000-grain weight were non-significant due to rice-establishment treatments. Amongst the weed-control treatments, butachlor 1.5 kg/ha followed by cono-weeding at 20 days recorded significantly more grains/panicle, panicle length, panicles/hill, and 1,000-grain weight than pretilachlor 0.75 kg/ha followed by

Table 1. Effect of nitrogen scheduling, weed management and crop establishment methods on weed biomass at 60 days, harvest and yield attributes (average data over 2 years)

Treatment	Weed biomass (g/m²)		Yield attributes			
	At 60 DAT	At harvest	Grains/ panicle	Panicle length (cm)	Panicles/ hill	1,000-grain weight (g)
Rice establishment method						
Puddled transplanting	8.1*(65.8)	11.8 (140.0)	183.3	18.1	10.7	14.1
Unpuddled transplanting	9.4 (89.5)	14.1 (199.8)	162.5	16.6	9.6	13.6
SEm±	0.13	0.20	2.52	0.20	0.12	0.17
CD (P=0.05)	0.39	0.58	7.23	0.57	0.36	NS
Weed management						
Butachlor 1.5 kg/ha (pre) *fb* azimsulfuron 35 g/ha at 15 DAT	11.2 (127.1)	16.6 (275.6)	151.7	16.2	11.4	15.2
Pretilachlor 0.75 kg/ha (pre) *fb* azimsulfuron 35 g/ha at 15 DAT	10.2 (104.4)	15.3 (234.8)	174.2	17.1	12.0	16.2
Butachlor 1.5 kg/ha *fb* cono-weeding at 20 DAT	7.4 (55.8)	11.1 (124.4)	206.1	18.8	13.1	17.4
2 hand-weedings at 20 and 40 DAT	1.0 (0.0)	1.0 (0.0)	235.6	20.6	14.4	19.2
Weedy	13.8 (192.5)	20.7 (431.1)	97.7	14.2	10.2	13.9
SEm±	0.21	0.32	3.99	0.31	0.20	0.28
CD (P=0.05)	0.62	0.92	11.44	0.91	0.57	0.80
Time of nitrogen application						
½ N at basal , ¼ N at tillering stage, ¼ N at panicle initiation stages	9.2 (86.4)	13.8 (192.5)	166.4	17.0	12.0	16.0
¼ N at 10 DAT, ½ N at tillering stage, ¼ N at panicle initiation stages	8.2 (68.6)	12.1 (146.2)	179.5	17.8	12.5	16.8
SEm±	0.10	0.16	2.03	0.16	0.10	0.15
CD (P=0.05)	0.29	0.45	5.81	0.46	0.29	0.45

*Weed biomass figures are transformed to $\sqrt{X+1}$ and actual figures are given in parentheses; N, Nitrogen; DAT, days after transplanting; *fb,* followed by

Table 2. Interaction effect of weed management and nitrogen scheduling on weed biomass (g/m^2) at 60 days after planting (DAT) (average data over 2 years)

Treatment /Time of nitrogen application	Weed management				
	Butachlor 1.5 kg/ha (pre) *fb* azimsulfuron 35 g/ha at 15 DAT	Pretilachlor 0.75 kg/ha (pre) *fb* azimsulfuron 35 g/ha at 15 DAT	Butachlor 1.5 kg/ha *fb* cono-weeding at 20 DAT	2 hand-weeding at 20 and 40 DAT	Weedy
½ N at basal, ¼ N at tillering stage, ¼ N at panicle initiation satge	12.4*(154.3)	10.8 (117.2)	7.4 (55.2)	1.0 (0.0)	14.7 (215.9)
¼ N at 10 DAT, ½ N at tillering stage, ¼ N at panicle initiation satge	10.1 (102.6)	9.6 (92.6)	7.4 (56.2)	1.0 (0.0)	13.0 (170.8)
			SEm±	CD (=0.05)	
		N at same W	0.32	0.96	
		W at same/diff N	0.38	1.13	

*Weed biomass figures are transformed to $\sqrt{x+1}$ and actual figures are given in parentheses; N, Nitrogen; DAT, days after transplanting; *fb*, followed by

azimsulfuron 35 g/ha at 15 days and butachlor 1.5 kg/ha followed by azimsulfuron 35 g/ha at 15 days. Pretilachlor 0.75 kg/ha followed by azimsulfuron 35 g/ha at 15 days resulted in significantly more grains/panicle, panicles/hill, and 1,000-grain weight than butachlor 1.5 kg/ha followed by azimsulfuron 35 g/ha at 15 days. Two hand-weedings recorded more grains/panicle, panicle length and panicles/ hill and 1,000-grain weight and were found significantly superior to all the weed-management treatments. Control of weeds by herbicides during early stages of rice followed by cono-weeding resulted in broad-spectrum control of weeds and reduced competition for growth resources that influenced the crop growth as evident by increased yield attributes. Similar findings were also observed by Ramachandra *et al.* (2012).

An initial reduced dose and delayed nitrogen application (one-fourth at 10 days, half at tillering stage and one-fourth at panicle-initiation stage) resulted in significantly more grains/panicle, panicle length, panicles/hill and 1,000-grain weight than conventional scheduling of nitrogen application (half at basal dressing, one-fourth at tillering stage and one-fourth at panicle-initiation stage). It might be due to synchronization of nitrogen application with crop demands and initial reduced dose might have influenced weeds germination.

Grain yield

Puddled transplanting method of rice establishment recorded significantly higher grain yield (Table 3) than unpuddled transplanting. The highest yield under puddled transplanting culture may be owing to better crop growth and yield-contributing parameters because of efficient utilization of available resources, which had direct impact on increasing the grain yield. The results support the findings of Jaiswal and Singh (2001). In case of weed-control treatments, butachlor 1.5 kg/ha followed by cono-weeding at 20 days recorded significantly higher grain yield over pretilachlor 0.75 kg/ha followed by azimsulfuron 35 g/ha at 15 days and butachlor 1.5 kg/ha followed by azimsulfuron 35 g/ha at 15 days during both the years. However, pretilachlor 0.75 kg/ha followed by azimsulfuron 35 g/ha at 15 days and butachlor 1.5 kg/ha followed by azimsulfuron 35 g/ha at 15 days recorded statistically comparable grain yield during both the years. Two hand-weedings at 20 and 40 days and weedy control recorded the maximum and the minimum grain yield respectively. Two hand-weedings recorded significantly higher grain yield among all the weed-management treatments during both the years. The relatively higher grain yield under these treatments might be owing to lower crop-weed competition and higher values of yield attributes. Our results are in agreement with the findings of

Kathirvelon and Vaiyapuri (2004).

An initial reduced dose and delayed nitrogen application (one-fourth at 10 days, half at tillering stage and one-fourth at panicle-initiation stage) obtained significantly higher grain yield in comparison to conventional scheduling of nitrogen application (half at basal dressing, one-fourth at tillering stage and one-fourth at panicle-initiation stage) during both the years. Delay in basal dose application till 10 days ensured establishment of seedlings and lesser growth of weeds, at the same time split application at maximum growth stage resulted in higher absorption and translocation of nitrogen to effective plant parts, viz. flag leaf and panicles, and reduced the losses, resulting in possible high grain yield. Awasthe (2009) also reported similar findings.

Nitrogen-use efficiency

Puddled transplanting showed significantly higher nitrogen uptake and nitrogen-use efficiency (Table 3) than unpuddled transplanting. In case of the weed-control treatments, butachlor 1.5 kg/ha followed by cono-weeding at 20 days recorded significantly higher nitrogen uptake and nitrogen-use efficiency than pretilachlor 0.75 kg/ha followed by azimsulfuron 35 g/ha at 15 days and butachlor 1.5 kg/ha followed by azimsulfuron 35 g/ha at 15 days. Two hand-weedings and weedy control recorded the maximum and the minimum nitrogen uptake and nitrogen-use efficiency respectively. An initial reduced dose and delayed nitrogen application (one-fourth at 10 days, half at tillering stage and one-fourth at panicle-initiation stage) revealed significantly higher nitrogen uptake and nitrogen-use efficiency.

Weed index

Puddled transplanting recorded lesser weed index than unpuddled transplanting (Table 3). Amongst the weed-management treatments, the minimum weed index was recorded under butachlor 1.5 kg/ha followed by cono-weeding at 20 days, whereas the maximum weed index was recorded under weedy. Initial reduced dose and delayed nitrogen application (one-fourth at 10 days, half at tillering stage and one-fourth at panicle-initiation stage)

Table 3. Effect of nitrogen scheduling, weed management and rice establishment methods on weed index, grain yield, nitrogen uptake, nitrogen use efficiency and economics (average data over 2 years).

Treatment	Grain yield (t/ha)			Weed index (%)	Nitrogen uptake (kg/ha)	Nitrogen-use efficiency (kg grain increase/kg N applied)	Economics Net returns (× 10³ ₹/ha)	B:C
	2010	2011	Pooled mean					
Rice establishment methods								
Puddled transplanting	4.64	4.75	4.69	10.8	65.7	39.2	52.86	2.52
Unpuddled transplanting	4.20	4.26	4.23	19.9	56.6	35.3	45.48	2.35
SEm±	0.06	0.07	0.04	-	1.23	0.38	.88	0.02
CD (P=0.05)	0.17	0.21	0.13	-	3.53	1.11	2.53	0.06
Weed management								
Butachlor 1.5 kg/ha (pre) *fb* azimsulfuron 35 g/ha at 15 DAT	4.37	4.42	4.39	20.8	52.5	36.7	48.72	2.47
Pretilachlor 0.75 kg/ha (pre) *fb* azimsulfuron 35 g/ha at 15 DAT	4.52	4.63	4.57	12.6	61.9	38.2	52.04	2.57
Butachlor 1.5 kg/ha *fb* cono-weeding at 20 DAT	4.93	5.03	4.98	9.0	73.1	41.5	60.01	2.84
2 hand-weedings at 20 and 40 DAT	5.42	5.53	5.47	0.0	89.4	45.6	61.34	2.51
Weedy	2.85	2.94	2.89	43.5	28.8	24.2	23.74	1.78
SEm±	0.09	0.11	0.07	-	1.94	0.61	1.39	0.03
CD (P=0.05)	0.28	0.33	0.21	-	5.58	1.76	4.01	0.10
Time of nitrogen application								
½ N at basal , ¼ N at tillering stage, ¼ N at panicle initiation stages	4.22	4.31	4.26	19.1	56.4	35.6	45.47	2.32
¼ N at 10 DAT, ½ N at tillering stage, ¼ N at panicle initiation stages	4.61	4.71	4.66	11.6	66.0	38.9	52.87	2.55
SEm±	0.04	0.05	0.03	-	0.91	0.30	.69	0.02
CD (P=0.05)	0.14	0.15	0.10	-	2.62	0.86	1.99	0.05

Pre, pre-emergence; DAT, days after transplanting; *fb,* followed by had the lower weed index than conventional scheduling of nitrogen application (half at basal dressing, one-fourth at tillering stage and one-fourth at panicle-initiation stage). It might be due to reduced crop-weed competition as evident by reduced weed biomass in respective treatments.

Economics

Puddled transplanting recorded higher net returns and benefit: cost ratio than unpuddled transplanting. Amongst the weed-control treatments, butachlor 1.5 kg/ha followed by cono-weeding at 20 days recorded significantly higher net returns and benefit: cost ratio than pretilachlor 0.75 kg/ha followed by azimsulfuron 35 g/ha at 15 days and butachlor 1.5 kg/ha followed by azimsulfuron 35 g/ha at 15 days. The higher net returns and benefit: cost ratio under these treatments was mainly owing to more grain yield and comparatively lower variable cost of cultivation compared to manual weeding and the other herbicidal treatments. Reddy (2010) also reported that pre-emergence herbicide application along with cono-weeding recorded the highest net returns and benefit: cost ratio.

An initial reduced dose and delayed nitrogen application (one-fourth at 10 days, half at tillering stage and one-fourth at panicle-initiation stage) recorded significantly more net returns and benefit: cost ratio than conventional scheduling of nitrogen application (half at basal dressing, one-fourth at tillering stage and one-fourth at panicle-initiation stage). This might be owing to higher grain yield in initial reduced dose and delayed nitrogen application than conventional scheduling of nitrogen. Awasthe (2009) and Sathia *et al.* (2009) also reported similar findings.

Thus rice establishment by puddled transplanting, weeds managed by butachlor 1.5 kg/ha followed by cono-weeding at 20 DAT and application of one-fourth N at 10 days, half N at tillering stage and one-fourth N at panicle-initiation stage was most remunerative in Varanasi conditions of Uttar Pradesh.

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