Indian Journal of Weed Science 48(4): 372–377, 2016
DOI: 10.5958/0974-8164.2016.00097.6

Interaction effect of nitrogen schedule and weed management on yield of direct-seeded rice

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Received: 25 September 2016; Revised: 17 November 2016

ABSTRACT

A field experiment was conducted at Agricultural Research Farm, Institute of Agricultural sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, during rainy season of 2011 and 2012 to study the effect of nitrogen schedule and weed management in direct-seeded rice under irrigated condition. The experiment comprised of 24 treatments including all the combinations of four nitrogen schedule and six weed management. The results indicated that the minimum weed density, total weed dry weight and depletion of nutrient was recorded under nitrogen schedule of ¼ 2 WAS (week after sowing) + ¼ 4 WAS + ¼ 6 WAS+ ¼ 8 WAS, which was statistically at par with $^1/_3$ 2 WAS + $^1/_3$ 4 WAS + $^1/_3$ 6 WAS and significantly lower than other nitrogen schedules. The maximum yield was recorded under nitrogen schedule at ¼ 2 WAS + ¼ 4 WAS + ¼ 6 WAS + ¼ 8 WAS, which was statistically at par with $^1/_3$ 2 WAS + $^1/_3$ 4 WAS + $^1/_3$ 6 WAS and which was significantly superior over other treatments. Significantly lower weed density, dry weight and nutrient depletion were recorded under application of pendimethalin 1.0 kg/ha *fb* bispyribac + carfentrazone (25 + 20 g/ha) and pendimethalin 1.0 kg/ha *fb* bispyribac + ethoxysulfuron (25 +18 g/ha), which were significantly superior over other treatments.

Key words: Direct-seeded rice (DSR), Interaction effect, Nitrogen schedule, Nutrient depletion, Weed management, Yield

Rice is the premier food crop of India and therefore, national food security system largely relies on the productivity of rice in different agro-ecosystems and physical conditions of soil. In South Asia, rice-based cropping systems account for more than 50% of the total land with rice grown in sequence of rice or upland crops like wheat, maize or legumes. Cultivation of rice by transplanting in rice-wheat is most popular in North India. This method requires puddling for field preparation to check percolation losses of water and control weeds effectively; however, destruction of soil structure that adversely affects growth and yield of succeeding crop in rotation is a major disadvantage and it is also a labor and water intensive method. Rice consumes about 3000-5000 litres of water to produce 1 kg grain, depending on the different rice cultivation methods. Under these situations, direct-rice seeding is one of the important alternate methods of rice establishment that avoid puddling and does not require submergence and thus reduce the overall water need for rice cultivation (Farooq *et al.*, 2011). Nitrogen use efficiency (NUE) of rice is usually low due to leaching, volatilization and denitrification losses. Moreover, direct-seeded rice soils are often exposed to dry and wet conditions and difference in N dynamics and losses pathways often results in different fertilizer recoveries in aerobic soils. Split application is one of the strategies for efficient use of N fertilizers throughout the growing season by synchronizing with plant demand, reducing denitrification losses and improved N uptake for maximum straw and grain yield and harvest index in DSR (Lampayan *et al.* 2010). Recently, Mahajan and Timsina (2011) evaluated response of DSR to different nitrogen rates when applied in four splits.

Weeds pose major problem in rice production due to the prevalence of congenial atmosphere during *Kharif* rainy season. The aerobic soil conditions and dry-tillage practices, besides alternate wetting and drying conditions, are conducive for germination and growth of highly competitive weeds, which cause grain yield losses of 50-91%. The direct-seeded rice stimulates more weed growth than transplanted rice, thus their management becomes more complex. Weed control, particularly during the initial stages of crop establishment is very essential in realizing higher yield. Manual weeding has become difficult because of labor scarcity and increased cost (Rao *et al.* 2007). Single herbicide may not provide an effective control due to wide diversity of weed flora observed in rice

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field, thus tank mix of herbicides are very effective to reduce the weed density. The combination of herbicides with nitrogen schedule have been reported for better control of weeds and maximum crop growth and yield in DSR (Sharma 2007 and Chaudhary *et al*. 2011). Therefore, this study was conducted to assess the performance of different herbicides under nitrogen schedule on direct-seeded rice.

MATERIALS AND METHODS

A field experiment was conducted at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (Uttar Pradesh), during rainy (*Kharif*) season of 2012 and 2013. The soil was Gangetic alluvial having sandy clay loam in texture with normal soil reaction (7.39), low organic carbon (0.43%), low available N (205.51 kg/ha), and medium in available P_2O_5 (23.21 kg/ha) and K_2O (221.50 kg/ha). The total rainfall received during crop-growing season of 2012 and 2013 was 665.6 and 780.8 mm, respectively. The experiment was laid out in split-plot design with 24 treatment combinations (4 nitrogen schedules and 6 weed management including weed free and weedy check) and replicated three times. The nitrogen schedule was subjected to main plots, *viz*. ¼ basal + ¾ 4 week after sowing (WAS), $^1/_3$ 2 WAS + $^1/_3$ 4 WAS + $^1/_3$ 6 WAS, ¼ 2 WAS + ¼ 4 WAS + ¼ 6 WAS + ¼ 8 WAS and ¼ basal + ½ 4 WAS + ¼ 6 WAS, while weed management was placed in sub plots, *viz*. weedy check, weed free, pendimethalin at 1.0 kg/ha, pendimethalin 1.0 kg/ha (PE) *fb* metsulfuron-methyl + chlorimuron (4 g/ha, POE), pendimethalin 1.0 kg/ ha (PE) *fb* bispyribac + carfentrazone (25 + 20 g/ha, POE) and pendimethalin 1.0 kg/ha (PE) followed by bispyribac + ethoxysulfuron (25 + 18 g/ha POE). Recommended dose of N, P and K were applied at 120 kg N/ha, 60 kg P_2O_5/ha and 40 kg K_2O/ha. Full dose of phosphorus and potash were applied as basal application and nitrogen was applied as treatment wise. Dry seed of '*HUR 105*' variety of rice at 40 kg/ ha was used for seeding of rice. Sowing was done manually with the help of spade at a spacing of row 20 cm. The herbicides were applied with the help of a hand-operated knapsack sprayer fitted with flat-fan nozzle. Weed density and weed dry weight data were collected at 20, 40, 60, 80 DAS and at harvest stage. The data on weeds were subjected to square-root transformation ($\sqrt{x+0.5}$) to normalize their distribution. Weeds were cut at ground level, washed with tap water, sundried, dried at 70°C for 48 hr and then weighed. Grain yield and its attributes were also recorded during the course of investigation at crop maturity. The data recorded on various parameters of rice crop were analyzed following standard statistical analysis of variance procedure.

RESULTS AND DISCUSSION

Weed flora

Major weed flora species infesting in the direct-seeded rice as observed in weedy check plots were, grasses, sedges and broad-leaved weeds. The critical analysis of data on relative composition of weed species indicated that among grassy weeds, *Echinocloa colona* and *Echinocloa crus-galli* were dominant weed species. Major sedges consisted of *Cyperus rotundus*, *Cyperus iria* and *Fimbristylis miliaceae*. Predominant broad-leaved weeds included *Eclipta alba, Ammannia baccifera, Caesulia axillaris* and *Phylanthus niruri*.

Nitrogen schedule had no significant influences on the total density of different group of weeds (grasses, sedge and broad-leaved weed) at 20, 40 DAS and harvest stages while it influenced significantly at 60 and 80 DAS except the grasses. In grasses, it influenced significantly only at 60 DAS. This shows that germination of weed seeds was not influenced significantly by the time of application of nitrogen. However, total weed density, their dry weight and nutrient depletion by weeds influenced significantly due to application of different nitrogen schedule (Table 1). The pooled data revealed that minimum weed density, total weed dry weight and nutrient depletion by weeds were recorded under nitrogen schedule at ¼ 2 WAS + ¼ 4 WAS + ¼ 6 WAS+ ¼ 8 WAS, which was statistically at par with $^1/_3$ 2 WAS + $^1/_3$ 4 WAS + $^1/_3$ 6 WAS and it was significantly lower than ¼ basal + $^3/_4$ 4 WAS, and ¼ basal + ½ 4 WAS + ¼ 6 WAS at all stages of observation except grass weeds. In grass weeds, the weed density was significantly reduced only at 60 DAS. This can be attributed to low vigorous growth of weeds due to skip of the application of nitrogen at the time of sowing, which resulted into suppression of total weed density, weed dry weight and nutrient depletion by weeds. Higher density of weeds, their dry weight and nutrient depletion by weeds were recorded under ¼ basal + ¾ 4 WAS, and ¼ basal + ½ 4 WAS + ¼ 6 WAS, which might have been due to the fact that under these treatments whole nitrogen doses were applied within month, which had better impact on emergence of weeds and growth, and poor crop growth resulted in higher weed dry weight and more nutrient depletion by weeds.

Table 1. Effect of nitrogen schedule and weed management on total weed density, total weed dry weight and nutrient depletion by weeds in direct-seeded rice (pooled over 2 year)

Treatment	Total weed density (m^2) at DAS					Dry weight of weeds (m^2) at DAS					N	P	K
	20	40	60	80	Harvest	20	40	60	80	Harvest	(kg/ha)	(kg/ha)	(kg/ha)
Nitrogen schedule													
$^1/_4$ basal + $^3/_4$ 4 weeks after sowing (WS)	9.22	9.49	11.48	11.10	10.58	3.64	4.60	10.34	11.61	12.04	3.96	1.84	4.56
	(101.3)	(116.9)	(166.6)	(155.7)	(141.8)	(16.0)	(28.0)	(138.8)	(172.5)	(186.2)	(19.28)	(3.35)	(25.38)
$^1/_3$ 2 WS + $^1/_3$ 4 WS + $^1/_3$ 6 WS	8.66	8.26	9.95	9.58	9.10	3.35	3.66	8.12	8.95	9.36	3.16	1.59	3.85
	(89.2)	(87.1)	(123.5)	(114.0)	(103.3)	(13.7)	(19.6)	(92.2)	(110.6)	(120.2)	(13.11)	(2.58)	(19.19)
$^1/_4$ 2 WS + $^1/_4$ 4 WS + $^1/_4$ 6 WS + $^1/_4$ 8 WS	8.41	8.06	9.50	8.98	8.77	3.18	3.41	7.63	8.47	8.77	3.00	1.48	3.67
	(83.7)	(83.6)	(112.5)	(100.2)	(95.9)	(12.3)	(16.8)	(81.7)	(97.8)	(103.7)	(11.87)	(2.11)	(17.64)
$^1/_4$ basal + $^1/_2$ 4 WS + $^1/_4$ 6 WS	8.89	9.18	10.98	10.52	9.98	3.45	4.36	9.99	10.70	11.10	3.85	1.83	4.45
	(94.1)	(108.4)	(151.5)	(140.1)	(125.7)	(14.4)	(25.4)	(131.3)	(148.9)	(159.6)	(18.71)	(3.44)	(24.46)
LSD (P=0.05)	0.38	0.59	0.45	0.72	0.36	0.21	0.30	0.62	0.60	NS	0.240	0.005	0.027
Weed management													
Pendimethalin at 1.0 kg/ha	10.79	12.76	14.68	14.14	13.56	4.14	5.97	13.23	14.71	15.27	4.91	2.21	5.75
	(116.5)	(163.2)	(216.9)	(201.3)	(184.8)	(17.2)	(36.1)	(177.2)	(218.5)	(235.5)	(25.30)	(4.63)	(34.50)
Pendimethalin1.0 kg/ha *fb* metsulfuron-ethyl +chlorimuron (2 + 2 g/ha)	9.81	8.57	11.04	10.62	10.12	3.97	4.44	10.38	11.59	12.09	3.93	1.88	4.79
	(96.0)	(73.7)	(12.4)	(113.5)	(102.6)	(15.8)	(20.2)	(109.6)	(136.6)	(148.7)	(16.08)	(3.25)	(23.93)
Pendimethalin 1.0 kg/ha *fb* bispyribac + carfentrazone (25 + 20 g/ha)	8.97	7.09	9.04	8.56	8.12	3.71	2.73	6.54	7.45	7.92	2.55	1.36	3.32
	(80.3)	(50.1)	(81.6)	(73.2)	(65.9)	(13.8)	(8.0)	(45.0)	(58.3)	(65.7)	(6.69)	(1.49)	(10.88)
Pendimethalin 1.0 kg/ha *fb* bispyribac + ethoxysulfuron (25 + 18 g/ha)	9.36	7.62	9.65	9.23	8.77	3.76	3.19	7.45	8.40	8.77	2.87	1.46	3.53
	(87.5)	(57.9)	(93.1)	(85.3)	(76.6)	(14.2)	(10.7)	(58.6)	(74.8)	(80.9)	(8.57)	(1.78)	(13.07)
Weedy check	13.12	15.74	17.76	17.01	16.38	4.85	7.72	16.54	17.43	17.90	6.01	2.50	6.80
	(172.2)	(249.1)	(317.0)	(291.6)	(270.1)	(23.6)	(59.8)	(275.7)	(306.4)	(323.7)	(37.84)	(6.07)	(47.63)
Weed free	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
	(0.0)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.0)	(0.00)	(0.00)	(0.00)
LSD (P=0.05)	0.34	0.39	0.37	0.38	0.36	0.15	0.24	0.51	0.50	0.51	0.175	0.008	0.025
N x S	NS	S	S	S	S	NS	S	S	S	S	S	S	S

Figures in parentheses are the original values; *fb* - Followed by; DAS - days after sowing

The pooled data indicated that all weed management treatments significantly lowered weed density, their weed dry weight and nutrient depletion than the weedy check (Table 1). Application of pendimethalin 1.0 kg/ha *fb* bispyribac + carfentrazone 25 + 20 g/ha was at par with pendimethalin 1.0 kg/ha *fb* bispyribac + ethoxysulfuron 25 + 18 g/ha and it was significantly superior over others treatments in respect of minimizing weed density, their dry weight, and nutrient depletion by weeds at different stages of observation. This might be attributed to more bio-efficiency of bispyribac, which effectively controlled wide diversified weeds. In addition, carfentrazone (Rawat *et al*. 2013, Singh *et al*. 2013) and ethoxysulfuron (Hussain 2008) have been reported to provide effective control for broad-leaved weeds and sedges in rice, and also for lowering the weeds population. Sequential application of pendimethalin *fb* tank mix of bispyribac with carfentrazone or ethoxysulfuron lowered the weed count than weedy check and sole application of pendimethalin. Alone application of pendimethalin was least effective in minimizing the density of weeds, dry weight and nutrient depletion as compared to sequential application of herbicides. This may be due to control of weeds by pre-emergence herbicides in early stages and post-emergence herbicides effectively controlled the later emerging weeds, particularly sedges and broad-leaved weeds as reported earlier for sequential application of bispyribac + carfentrazone by Khaliq *et al.* (2012). The highest NPK depletion by weeds was recorded under alone application of pendimethalin. It was due to maximum total weed dry matter under this treatment as nutrient depletion is positively correlated with weed dry matter accumulation. This is in agreement with the findings of Singh *et al.* (2013).

Crop

Effect on yield attributes and yield: Nitrogen schedule and weed-management practices had significant effect on yield attributes but nitrogen schedule did not significantly influenced the test weight and harvest index (Table 2). Pooled data indicated that the maximum grain yield (4092.81 kg/ha) and yield attributes, *ie* effective tiller/m^2 (69.7), number of grains/panicle (111.2), panicle length (24.0 cm), weight of panicle (2.88 g), test weight (23.8 g) and harvest index (40.3%) recorded under nitrogen schedule at ¼ 2 WAS + ¼ 4 WAS + ¼ 6 WAS+ ¼ 8 WAS were statistically at par with $^1/_3$ 2 WAS + $^1/_3$ 4 WAS + $^1/_3$ 6 WAS and it was significantly higher than remaining nitrogen schedule treatments. It clearly showed that skipping the nitrogen dose at sowing time and applying the same at two weeks after sowing was better for crop growth due to increases nutrient use efficiency, and also less chance of nitrogen losses due to leaching, immobilization and denitrification etc. The soil has sufficient amount of nitrogen for fulfill the initial requirement of crop. Nitrogen schedule with four split of ¼ of total nitrogen was given at 2 weeks after sowing (WAS) to 8 WAS of crop stage gave significantly higher yield than rest two nitrogen schedule where ¼ of total nitrogen was applied as basal and remaining at 4 and 6 WAS in N_1 and N_4 nitrogen schedule, respectively. Splits application maintained continuous supply of nutrients which might have favored the crop for good growth, yield attributes and finally the yield of rice. This might to be more favorable for higher grain attributes and grain yield. This confirms the earlier findings where nitrogen dose was reported better in splits (Sharma *et al.* (2007), Mahajan and Timsina (2011) and Rehman *et al.* (2013).

The highest yield attributes and yield was recorded in weed free plots. Among the weed management treatment, the maximum grain yield (4.62 t/ha) and yield attributes, effective tiller per m row length (70.13), number of grains/panicle (114.13), panicle length (24.52 cm), weight of panicle (2.87/g), test weight (24.19/g) and harvest index (42.43%) were recorded with application of pendimethalin 1 kg/ha *fb* bispyribac + carfentrazone 25 + 20 g/ha, which was at par with pendimethalin 1.0 kg/ha *fb* bispyribac + ethoxysulfuron 25 + 18 g/ ha and it was significantly superior over others herbicidal treatments, thereby realizing an increase of 67.5% yield over weedy check and it was at par with weed-free plots. Application of pendimethalin *fb* tank mix of bispyribac with carfentrazone and ethoxysulfuron showed greater synergy in terms of increased weed control efficiency, yield attributes and yield of rice in comparison to other weed management treatments. These results can be attributed due to minimizing crop-weed competition, better nutrient uptake by crop which marked improvement in biomass, maximum number of effective tillers and ultimately improved the yield-attributing components and yield of crop. The minimum grain yield was recorded under weedy check which was attributed due to more weed growth, total weed dry weight and poor yield attributing characters. Results were in agreement with the findings of Veeraputhiran and Balasubramanian (2013), and Khaliq *et al.* (2012).

The pooled data of two years indicated that, interaction effect of nitrogen schedule and weed management practices were found significant for total weed density and dry weight at 60 days after sowing, number of effective tillers and grain yield of rice (Table 3, 4). Irrespective of nitrogen schedule, minimum weed density and weed dry weight was recorded under nitrogen schedule of ¼ 2 WAS + ¼ 4 WAS + ¼ 6 WAS+ ¼ 8 WAS with all the herbicidal treatments. The minimum weed density and dry weight of weeds was recorded under application of pendimethalin 1.0 kg/ha *fb* bispyribac + carfentrazone 25 + 20 g/ha in all the nitrogen schedules. Application of pendimethalin 1.0 kg/ha *fb* bispyribac + carfentra zone 25 + 20 g/ha under nitrogen

Table 2. Effect of nitrogen schedule and weed management on yield attributes and yield of crop in direct seeded rice (pooled over 2 year)

Treatment	No. of effective tillers/m	Panicle weight (g)	No. of spikelets/ panicle	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	HI (%)	Test weight (g)
Nitrogen Schedule								
$^1/_4$ basal + $^3/_4$ 4 weeks after sowing (WS)	53.61	2.41	97.14	3.42	5.07	8.49	39.16	23.16
$^1/_3$ 2 WS + $^1/_3$ 4 WS + $^1/_3$ 6 WS	65.00	2.67	105.86	4.05	5.77	9.82	40.07	23.67
$^1/_4$ 2 WS + $^1/_4$ 4 WS + $^1/_4$ 6 WS + $^1/_4$ 8 WS	69.72	2.88	111.19	4.09	5.82	9.91	40.33	23.85
$^1/_4$ basal + $^1/_2$ 4 WS + $^1/_4$ 6 WS	57.08	2.56	100.64	3.70	5.41	9.11	39.75	23.62
LSD (P=0.05)	5.81	0.31	8.70	0.25	0.48	0.71	1.17	0.74
Weed management								
Pendimethalin at 1.0 kg/ha	53.75	2.46	95.79	3.16	4.71	7.87	40.15	23.20
Pendimethalin1.0 kg/ha *fb* metsulfuron-methyl + chlorimuron (2 + 2 g/ha)	61.50	2.64	105.04	4.04	5.76	9.80	41.17	23.63
Pendimethalin 1.0 kg/ha *fb* bispyribac + carfentrazone (25 + 20 g/ha)	70.13	2.87	114.13	4.62	6.26	10.88	42.43	24.19
Pendimethalin 1.0 kg/ha *fb* bispyribac + ethoxysulfuron (25 + 18.0 g/ha)	66.33	2.69	109.38	4.51	6.22	10.73	42.01	24.02
Weedy check	42.75	2.11	76.17	1.50	3.66	5.16	29.36	22.15
Weed free	73.67	3.00	121.75	5.06	6.49	11.55	43.84	24.27
LSD (P=0.05)	3.31	0.20	6.69	0.16	0.30	0.41	1.16	0.56
N x S	S		NS	NS	S	S	S	NS

Table 3. Interaction effect of nitrogen schedule and weed management on total weed density, total dry weight, number of effective tillers in one-meter row length and grain yield of crop in direct-seeded rice (pooled over 2 year)

Weed management	Total weed density at 60 DAS (m^2)				Total weed dry weight at 60 DAS (g/m^2)				Effective tillers one meter row length				Grain yield (t/ha)			
	N_1	N_2	N_3	N_4	N_1	N_2	N_3	N_4	N_1	N_2	N_3	N_4	N_1	N_2	N_3	N_4
Pendimethalin at 1.0 kg/ha	16.2 (261)	13.7 (187)	13.2 (175)	15.6 (242)	14.5 (212)	12.6 (158)	11.4 (131)	14.4 (207)	49.0	55.7	58.2	52.2	2.66	3.68	3.21	3.10
Pendimethalin 1.0 kg/ha *fb* metsulfuron-methyl + chlorimuron (2 + 2 g/ha)	12.3 (150)	10.5 (110)	9.7 (94)	11.6 (135)	11.8 (139)	9.6 (92)	8.7 (76)	11.4 (131)	55.0	65.2	66.7	59.2	3.48	4.45	4.33	3.89
Pendimethalin 1.0 kg/ha *fb* bispyribac + carf entrazone (25 + 20 g/ha)	9.8 (96)	8.7 (76)	8.3 (68)	9.3 (87)	8.2 (68)	5.0 (26)	5.2 (27)	7.7 (59)	58.2	75.7	84.3	62.3	4.10	4.74	5.09	4.54
Pendimethalin1.0 kg/ha *fb* bispyribac + ethoxysulfuron (25 + 18 g/ha)	10.3 (105)	9.2 (84)	9.1 (81)	10.1 (101)	9.5 (90)	6.1 (37)	5.5 (30)	8.7 (77)	57.3	71.2	75.0	61.8	4.08	4.74	4.92	4.40
Weedy check	19.7 (387)	16.8 (283)	16.0 (256)	18.5 (22)	18.0 (342)	15.5 (240)	15.0 (225)	17.7 (314)	39.3	44.5	47.2	40.0	1.25	1.56	1.77	1.41
Weed free	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (0)	62.8	77.8	87.0	67.0	4.93	5.15	5.23	4.87
W at same N	0.26				0.36				2.32				0.11			
LSD (P=0.05)	0.74				1.02				6.63				0.31			
N at same W	0.27				0.37				270				0.12			
LSD (P=0.05)	0.78				1.06				7.72				0.35			

Figures in parentheses are the original values

N_1- $^1/_4$ basal + $^3/_4$ 4 weeks after sowing (WS), **N_2-** $^1/_3$ 2 WS +$^1/_3$ 4 WS +$^1/_3$ 6 WS, **N_3-** $^1/_4$ 2 WS + $^1/_4$ 4 WS + $^1/_4$ 6 WS +$^1/_4$ 8 WS, **N_4-** 4 basal + $^1/_2$ 4WS + $^1/_4$ 6 WS; *fb*- followed by

schedule at ¼ 2 WAS + ¼ 4 WAS + ¼ 6 WAS+ ¼ 8 WAS was most effective in reducing the weed density and weed dry weight and found at par with pendimethalin 1.0 kg/ha *fb* bispyribac + ethoxysulfuron 25 + 18 g/ha significantly superior over other treatments.

Nitrogen schedule at ¼ 2 WAS + ¼ 4 WAS + ¼ 6 WAS+ ¼ 8 WAS recorded more number of effective tillers of rice under all the weed management treatments (Table 3). The treatment combination of nitrogen schedule at ¼ 2 WAS + ¼ 4 WAS + ¼ 6 WAS+ ¼ 8 WS and pendimethalin 1.0 kg/ha *fb* bispyribac + carfentrazone 25 + 20 g/ha produced significantly more number of panicles over all the other treatment combinations, also recorded maximum grain yield and it was found at par with pendimethalin 1.0 kg/ha *fb* bispyribac + ethoxysulfuron 25 + 18 g/ha, and also with their counterparts under nitrogen schedule of $^1/_3$ 2 WS + $^1/_3$ 4 WS + $^1/_3$ 6 WS but these were significantly superior over remaining treatment combinations. While the maximum grain yield was recorded under weed free plots due no weed crop competition during whole period of crop growth, and minimum grain yield was recorded under weedy check in all the nitrogen schedules. This was owing to the fact that all the weed management treatments under different nitrogen schedule produced maximum crop growth, and thereby the increased accumulation of photosynthates in reproductive parts, which ultimately brought about marked improvement in yield.

Total nutrient uptake by crop

Significant effect of nitrogen schedule and weed management treatments on total nutrient uptake of nitrogen, phosphorus and potassium by crop was observed during both the years of experimentation (Table 4). The pooled data clearly indicated that maximum total nitrogen, phosphorus and potassium uptake were recorded under ¼ 2 WAS + ¼ 4 WAS + ¼ 6 WAS+ ¼ 8 WAS, which was found at par with $^1/_3$ 2 WAS + $^1/_3$ 4 WAS + $^1/_3$ 6 WAS and it was significantly superior to rest nitrogen schedules during both the years. This was mainly due to splitting of whole nitrogen in to four split in equal part of ¼ and also in three split in to $^1/_3$ part gave similar results, as it might have helped in minimized the nitrogen losses through uptake by weeds, leaching and denitrification *etc*. Ultimately, it led to more nutrients availability to the crop and resulted in vigorous crop growth and development. Split application of N has been reported as the best method to improve N fertilizer use efficiency (Ali *et al.* 2007) and improve nitrogen uptake.

Amongst weed management treatments, higher total nitrogen, phosphorus and potassium uptake was recorded under application of pendimethalin 1.0 kg/ha *fb* bispyribac + carfentrazone 20 + 20 g/ha, which was found at par with pendimethalin 1.0 kg/ha *fb* bispyribac + ethoxysulfuron 25 + 18 g/ha and it was significantly superior over rest of the herbicidal treatments during both the years. But, highest total

Table 4. Interaction effect of nitrogen schedule and weed management on nutrient depletion (kg/ha) by weeds at 60 DAS

Weed management	Nitrogen				Phosphorus				Potassium			
	N_1	N_2	N_3	N_4	N_1	N_2	N_3	N_4	N_1	N_2	N_3	N_4
Pendimethalin 1.0 kg/ha (PE)	5.34 (28.1)	4.58 (20.4)	4.30 (18.1)	5.40 (28.8)	2.34 (5.0)	2.13 (4.0)	2.01 (3.5)	2.04 (5.1)	6.06 (36.3)	5.72 (32.2)	5.27 (27.3)	5.96 (35.0)
Pendimethalin 1.0 kg/ha (PE) *fb* metsulfuron-methyl + chlorimuron (2 + 2 g)/has (PO)	4.46 (19.4)	3.60 (12.5)	3.35 (10.8)	4.31 (18.1)	2.04 (3.7)	1.81 (2.8)	1.66 (2.3)	2.02 (3.6)	5.25 (27.1)	4.62 (20.9)	4.19 (17.1)	5.07 (25.2)
Pendimethalin at 1.0 kg/ha (PE) *fb* bispyribac + carfentrazone (25+20g)/ha (PO).	3.15 (9.5)	2.04 (3.7)	2.09 (3.9)	2.92 (8.0)	1.60 (2.1)	1.13 (0.8)	1.20 (0.9)	1.50 (1.8)	3.79 (13.9)	2.60 (6.3)	2.77 (7.2)	3.71 (13.3)
Pendimethalin 1.0 kg/ha (PE) *fb* bispyribac + ethoxysulfuron (25 + 18g)/ha (PO).	3.59 (12.4)	2.38 (5.2)	2.16 (4.2)	3.33 (10.6)	1.73 (2.5)	1.24 (1.0)	1.18 (0.9)	1.67 (2.3)	4.28 (17.8)	3.00 (8.5)	2.75 (7.1)	4.08 (16.2)
Weedy check	6.50 (41.8)	5.66 (31.6)	5.41 (28.9)	6.45 (41.2)	2.62 (6.4)	2.53 (5.9)	2.15 (4.1)	2.69 (6.7)	7.25 (52.1)	6.45 (41.0)	6.34 (39.7)	7.15 (50.6)
Weed free	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)
	LSD (P=0.05)				LSD (P=0.05)				LSD (P=0.05)			
W at same level of N	0.12		0.35		0.005		0.015		0.01		0.05	
N at same level of W	0.13		0.38		0.005		0.015		0.01		0.05	

nitrogen, phosphorus and potassium uptake by crop was associated with weed free treatment, which was significantly superior to all herbicidal treatments. This was owing to lower nutrient depletion by weeds under these treatments due to less weed infestation and depletion of nutrient. Hence, it appears that under competition between crop and weed for nutrients, both could not utilize these to the maximum extent. These were in close proximity with findings of Sharma (2007) and Chaudhary *et al.* (2011).

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