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EFFECTS OF NITROGEN AND DIFFERENT RATES OF PENDIMETHALIN WITH BISPYRIBAC-SODIUM ON DIRECT-SEEDED *AUS* RICE

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Abstract

The study was conducted at Sher-e-Bangla Agricultural University in Bangladesh, aiming to investigate the effects of nitrogen rates and herbicides on the competitiveness and yield parameters of dry direct-seeded rice (DSR) from March to July 2022. There were two factors in the experiment: nitrogen rates of 60 kg ha^{-1} (N_{60}) and 80 kg ha^{-1} (N_{80}), and the application of pre-emergent herbicide pendimethalin followed by post-emergent herbicide bispyribac-sodium. The herbicide treatments included: no weeding (H_0), pendimethalin at 1000 g a.i. ha^{-1} (H_1), bispyribac-sodium at 25 g a.i ha^{-1} (H_2), pendimethalin at 500 g a.i. ha^{-1} combined with bispyribac-sodium at 15 g a.i. ha^{-1} (H_3), pendimethalin at 1000 g a.i. combined with bispyribac-sodium at 30 g a.i. ha^{-1} (H_4), and pendimethalin at 1500 g a.i. ha^{-1} combined with bispyribac-sodium at 45 g a.i. ha^{-1} (H_5). The split-plot design consisted of 12 treatment combinations and 3 replications, with main plots for nitrogen rates and sub-plots for herbicidal treatments using rice var. BRRI dhan98. The result showed that the highest tiller number $hill^{-1}$ was recorded for 80 kg ha^{-1} combined with pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1} at 30, 45, 60, and 75 DAS, respectively. The study also exhibits the impact of nitrogen rates and herbicides on the dry weight of plants in BRRI dhan98 under the DSR system. Nitrogen rates did not significantly affect the dry weights of plants at 15, 30, and 45 days after sowing (DAS). However, the nitrogen rate of 80 kg N ha^{-1} resulted in the highest dry weight at 60 and 75 DAS. The study also found that the biological yield and harvest index of var. BRRI dhan98 were better (9.41 and 47.74, respectively) in 80 kg ha^{-1} combined with pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1}.

Introduction

Direct-seeded cultivation involves sowing the rice seeds directly in the field without the urgency of a nursery or transplanting operations (Bista, 2018). Though weed management remains a threat, direct-seeded rice (DSR) is achieving popularity in Asia as it is a climate-smart and resource-efficient production method (Ahmed *et al.,* 2020). Direct-seeded rice is a promising alternative to traditional transplanting systems. The usual method is water, labor, and energy intensive. On the contrary, DSR enhances planting efficiency and soil health, and reduces methane emissions along with retrenching the labor requirement by 11-66% compared to pre-germinated rice (Rashid *et al.,* 2009; Kumar and Ladha, 2011).

In comparison with the puddled transplanted rice (PTR) system, weeds compete more intensively in the DSR system for resources with the crop seedlings starting from the germination stage (Chauhan and Johnson, 2011; Chauhan and Opeña, 2012). A 70-80%

grain yield of *Aus* rice could be significantly hampered in the case of an improper weed management system (BRRI, 2008). Among the weeding methods, manual weeding is widely used in Bangladesh. Again, the farmers mix either pre-emergence (PRE) or post-emergence (POST) herbicides with water for easy application. However, this method may not be enough to control the vast weed species in DSR fields (Chauhan and Opeña, 2012). Seba (2022) also found that the application of the pre herbicide pendimethalin, succeeded by the post herbicide bispyribac-sodium, effectively mitigates weed proliferation and checks the emergence of resistant weed biotypes in the DSR system. The impacts of herbicides in DSR fields can fluctuate based on the N fertility levels present in the soil. Elevated nitrogen applications can alter the biochemical properties of both the soil and the plants, potentially augmenting or diminishing the absorption and efficacy of specific herbicides (Brochado *et al.,* 2023). The study aims to compare N and herbicide requirements in DSR and evaluate the efficacy of pre-emergence pendimethalin followed by post-emergence bispyribac-sodium combinations.

Materials and Methods

The field experiment studied the combined effects of nitrogen and pendimethalin, along with varying rates of bispyribac-sodium, on the growth and yield of *Aus* rice under dry direct-seeded conditions at Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, from March to July 2022. The experimental field was located in AEZ-28 (The Modhupur Tract), with a pH range of 5.8 to 6.5. The soil was classified as silty clay, and rainfall during the growing period varied from 17 mm to 390.7 mm. *Aus* rice var. BRRI dhan98 was used as the experimental crop. There were two factors in the experiment: nitrogen rates of 60 kg ha^{-1} (N_{60}) and 80 kg ha^{-1} (N_{80}), and the application of pre-emergent herbicide pendimethalin followed by post-emergent herbicide bispyribac-sodium. The herbicide treatments included: no weeding (H_0), pendimethalin at 1000 g a.i. ha^{-1} (H_1), bispyribac-sodium at 25 g a.i. ha^{-1} (H_2), pendimethalin at 500 g a.i. ha^{-1} combined with bispyribac-sodium at 15 g a.i. ha^{-1} (H_3), pendimethalin at 1000 g a.i. ha^{-1} combined with bispyribac-sodium at 30 g a.i. ha^{-1} (H_4), and pendimethalin at 1500 g a.i. ha^{-1} combined with bispyribac-sodium at 45 g a.i. ha^{-1} (H_5). The study employed a split-plot design with 12 treatment combinations, each replicated three times. The main plots varied in nitrogen levels, while the sub-plots incorporated different rates of pendimethalin and bispyribac-sodium. On March 21, 2022, the field was cultivated with a power tiller and irrigated after three ploughs and cross-ploughs. Weeds and pests were cleared. By March 27, the final layout was completed; each plot was leveled with a wooden board. Nutrients, including phosphorus (P), potassium (K), sulfur (S), and zinc (Zn), were applied to rice per BRRI's *Aus* rice recommendations. Fertilizer doses included: triple superphosphate (90 kg ha^{-1}), muriate of potash (40 kg ha^{-1}), gypsum (60 kg ha^{-1}), and zinc sulfate (10 kg ha^{-1}). All fertilizers, except urea, were applied during land preparation, with urea split into three applications: first at preparation, then at 25 days and 50 days after sowing, based on treatments. The field was irrigated only at the flowering stage of the tested crop. The data were analyzed and mean differences were assessed by using the least significant difference (LSD) test at a 5% significance level.

Results and Discussion

Total number of tillers hill^{-1}

The total number of tillers hill^{-1} did not significantly differ across different nitrogen rates except at 75 days after sowing (DAS) (Table 1). The highest (9) number of total tillers hill^{-1} at 75 DAS was found with the N_{80} treatment, while the lowest (8) from the N_{60} treatment. The total number of tillers hill^{-1} of direct-seeded *Aus* rice varied significantly as a result of the herbicides used (Table 1). Experimental results revealed that, at 15 DAS, the maximum tiller number hill^{-1} (5) was recorded from the combined pre-emergence herbicide pendimethalin 1000 g a.i. ha^{-1} +

post-emergence bispyribac-sodium 30 g a.i. ha^{-1}. At 30 DAS, the maximum tiller number $hill^{-1}$ (9) from mixed herbicide pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1}. At 45 DAS, the highest tiller number $hill^{-1}$ (13) was recorded from the pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1} (H_4). At 60 DAS, the maximum tiller number in $hill^{-1}$ (13) was recorded for pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1} (H_4). The combined impact of pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1} (H_4) resulted in the highest tiller number $hill^{-1}$ in both nitrogen doses (Table 1). The tiller number $hill^{-1}$ for N_{80} combined with H_4 is 5, 9, 13, and 13 at 30, 45, 60, and 75 DAS, respectively. The combined effect of pendimethalin 1500 g a.i. ha^{-1} + bispyribac-sodium 45 g a.i. ha^{-1} (H_5) was also similar at 30, 45, 60, and 75 DAS, respectively, for $N_{80}H_5$. On the other hand, $N_{60}H_0$ resulted in the lowest tillers number $hill^{-1}$.

Table 1. Effect of nitrogen rates and pre and post-emergence herbicides rates on tiller number $hill^{-1}$ of var. BRRI dhan98 under DSR system

Treatments	Number of tillers			
	30 DAS	45 DAS	60 DAS	75 DAS
Nitrogen levels				
N_{60}	3.83	6.38	8.89	8.00 b
N_{80}	3.61	6.61	9.22	9.22 a
LSD $_{(0.05)}$	NS	NS	NS	0.48
CV (%)	8.96	15.60	3.19	3.87
Pendimethalin fb. Bispyribac-sodium rates				
H_0	3.50 bc	4.67 d	6.83 d	4.17 *e*
H_1	3.67 b	6.17 c	8.83 c	8.83 c
H_2	3.00 c	4.67 d	6.17 d	6.17 d
H_3	3.83 b	7.83 b	9.83 b	9.83 b
H_4	4.67 a	9.00 a	12.83 a	12.83 a
H_5	3.67 b	6.67 c	9.83 b	9.83 b
LSD $_{(0.05)}$	0.55	0.77	0.68	0.67
CV (%)	12.34	9.80	6.27	6.48
Nitrogen levels × Pendimethalin fb. Bispyribac-sodium rates				
$N_{60}H_0$	3.67 bc	4.33 f	5.33 g	0.00 h
$N_{60}H_1$	4.00 ab	5.33 *ef*	9.00 de	9.00 de
$N_{60}H_2$	3.00 c	5.00 *ef*	6.67 f	6.67 f
$N_{60}H_3$	4.00 ab	7.67 bc	9.33 d	9.33 d
$N_{60}H_4$	4.67 a	8.67 ab	12.33 b	12.33 b
$N_{60}H_5$	3.67 bc	7.33 cd	10.67 c	10.67 c
$N_{80}H_0$	3.33 bc	5.00 *ef*	8.33 *e*	8.33 *e*
$N_{80}H_1$	3.33 bc	7.00 cd	8.67 de	8.67 de
$N_{80}H_2$	3.00 c	4.33 f	5.67 g	5.67 g
$N_{80}H_3$	3.67 bc	8.00 bc	10.33 c	10.33 c
$N_{80}H_4$	4.67 a	9.33 a	13.33 a	13.33 a
$N_{80}H_5$	3.67 bc	6.00 de	9.00 de	9.00 de
LSD $_{(0.05)}$	0.83	1.65	0.95	0.96
CV (%)	12.34	9.80	6.27	6.48

Here: N_{60}=60 kg N ha^{-1} and N_{80}=80 kg N ha^{-1}; H_0= No weeding, H_1= pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 0 g a.i. ha^{-1}; H_2= pendimethalin 0 g a.i. ha^{-1} + bispyribac-sodium 25 g a.i. ha^{-1}; H_3= pendimethalin 500 g a.i. ha^{-1} + bispyribac-sodium 15 g a.i. ha^{-1}; H_4= pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1}; H_5= pendimethalin 1500 g a.i. ha^{-1} + bispyribac-sodium 45 g a.i. ha^{-1}

Dry weight of plants

Though nitrogen rates didn't play a role in causing significant differences in dry weights of plants at 15, 30, and 45 DAS but 80 kg N ha^{-1} resulted in the highest dry weight at 60 and 75 DAS (Table 2).

Table 2. Effect of nitrogen rates and pre and post-emergence herbicide rates on the dry weight of plants of var. BRRIdhan98 under the DSR system

Treatments	Dry Weight (g $plant^{-1}$)				
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Nitrogen levels					
N_{60}	2.42	5.58	12.95	29.21 b	31.21 b
N_{80}	2.53	5.00	14.08	35.19 a	37.03 a
LSD (0.05)	NS	NS	NS	1.12	0.97
CV (%)	11.17	15.85	6.09	2.43	1.99
Pendimethalin fb. Bispyribac-sodium rates					
H_0	1.85 c	4.60 d	9.54 d	14.75 *e*	11.52 *e*
H_1	1.71 c	5.96 ab	13.95 b	29.97 c	36.04 c
H_2	2.84 b	5.42 bc	13.70 b	27.01 d	27.48 d
H_3	1.87 c	4.15 d	12.39 c	39.44 b	40.92 b
H_4	3.70 a	6.40 a	15.64 a	42.23 a	44.90 a
H_5	2.88 b	5.22 c	15.88 a	39.81 b	43.85 a
LSD (0.05)	0.41	0.57	1.43	1.49	1.45
CV (%)	13.79	9.01	4.60	3.83	3.52
Nitrogen levels × Pendimethalin fb. Bispyribac-sodium rates					
$N_{60}H_0$	1.19 fg	4.42 de	7.60 g	8.30 j	0.00 g
$N_{60}H_1$	2.53 b-d	6.60 ab	13.32 cd	26.06 h	38.26 c
$N_{60}H_2$	2.78 bc	6.27 ab	13.82 cd	25.72 h	26.54 *e*
$N_{60}H_3$	1.71 *ef*	4.29 de	11.84 *ef*	38.32 de	40.97 b
$N_{60}H_4$	3.69 a	6.80 a	15.13 ab	39.76 cd	41.24 b
$N_{60}H_5$	2.61 b-d	5.09 c-*e*	16.01 ab	37.11 *e*	40.24 bc
$N_{80}H_0$	2.51 cd	4.77 de	11.47 f	21.19 i	23.04 f
$N_{80}H_1$	0.89 g	5.32 b-d	14.59 bc	33.88 f	33.83 d
$N_{80}H_2$	2.91 bc	4.56 de	13.58 cd	28.31 g	28.42 *e*
$N_{80}H_3$	2.02 de	4.02 *e*	12.93 de	40.56 bc	40.87 b
$N_{80}H_4$	3.71 a	6.00 a-c	16.16 a	44.69 a	48.55 a
$N_{80}H_5$	3.15 ab	5.36 b-d	15.75 ab	42.52 b	47.46 a
LSD (0.05)	0.63	1.33	1.43	2.15	2.05
CV (%)	13.79	9.01	4.60	3.83	3.52

Here: N_{60}=60 kg N ha^{-1} and N_{80}=80 kg N ha^{-1}; H_0= No weeding, H_1= pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 0 g a.i. ha^{-1}; H_2= pendimethalin 0 g a.i. ha^{-1} + bispyribac-sodium 25 g a.i. ha^{-1}; H_3= pendimethalin 500 g a.i. ha^{-1} + bispyribac-sodium 15 g a.i. ha^{-1}; H_4= pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1}; H_5= pendimethalin 1500 g a.i. ha^{-1} + bispyribac-sodium 45 g a.i. ha^{-1}

Dry weight of plants significantly differed due to the effect of herbicides (Table 2). At 15 DAS, the maximum dry weight (g) (3.70) was recorded from the combined pre-emergence

herbicide pendimethalin 1000 g a.i. ha^{-1} + post-emergence bispyribac-sodium 30 g ai ha^{-1} (H_4). At 30 DAS, a similar trend was followed. At 45 DAS, the highest dry weight (g) (15.88) was recorded from the pendimethalin 1500 g a.i. ha^{-1} + bispyribac-Sodium 45 g a.i. ha^{-1} (H_5). At 60 DAS, the maximum dry weight (g) (39.81) was recorded from the pendimethalin 1000 g a.i. ha^{-1} + bispyribac-Sodium 30 g a.i. ha^{-1} (H_4). Lodhi (2016) also found that weed control treatments significantly impact dry matter accumulation after sowing. Weedy check plots had the lowest dry matter production but increased significantly with weed control treatments at all growth intervals. Pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1} (H_4) resulted in the dry weight (g) in both nitrogen doses (Table 2). Dry weight (g) for $N_{80}H_4$ was 3.71, 6.00, 16.16, 44.69, and 48.55 at 15, 30, 45, 60, and 75 DAS, respectively. The effect of 80 kg N ha^{-1} and pendimethalin 1500 g a.i. ha^{-1} + bispyribac-sodium 45 g a.i. ha^{-1} (H_5) was also satisfactory for $N_{80}H_5$. On the other hand, $N_{60}H_0$ resulted in the lowest dry weight (g).

No. of panicles m^{-2}

The number of panicles m^{-2} was significantly affected by nitrogen rates. The maximum number of panicles m^{-2} was recorded with 80 kg N ha^{-1}, compared with 60 kg N ha^{-1} was 151 m^{-2} (Table 3). Panicle number (250 m^{-2}) was higher in the herbicide-treated plots than in the weedy check plots and was the highest in the highest dose of pre-post emergence herbicide, i.e., pendimethalin 1500 g a.i. ha^{-1} + bispyribac-sodium 45 g a.i. ha^{-1} (H_5) (Table 3). On the other hand, the lowest number of panicles was observed at the plots from the control (0 m^{-2}). Similar results were also noted by Hossain (2015). The combined effect, pendimethalin 1500 g a.i. ha^{-1} + bispyribac-sodium 45 g a.i. ha^{-1} (H_5) resulted in the highest number of panicles m^{-2} (255 m^{-2}) at the nitrogen dose of 60 kg N ha^{-1} (Table 3). On the other hand, $N_{60}H_0$ resulted in the lowest no. of panicles m^{-2} (0 m^{-2}).

Panicle length (cm)

The panicle length (cm) was significantly affected by nitrogen rates. The highest panicle length (14.87 cm) was recorded for the plots treated with 80 kg N ha^{-1}, (Table 3). The panicle length (19.55 cm) was higher in the herbicide-treated plots than in the weedy check plots and gave the highest, followed by pre-post emergence herbicide, i.e., pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1} (H_4) (Table 3). On the other hand, the lowest panicle length (cm) was observed at the control plot. According to research by Jabran *et al.,* (2012), using herbicides to suppress weeds produces longer panicles than the weedy check (control). Pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1} (H_4) resulted in the maximum panicle length (20.56 cm) at 80 kg N ha^{-1} (Table 3), followed by $N_{80}H_5$ with 80 kg N ha^{-1}, and the herbicide dose was pendimethalin 1500 g a.i. ha^{-1} + bispyribac-Sodium 45 g a.i. ha^{-1} (19.59 cm). On the other hand, $N_{60}H_0$ resulted in the lowest no. of panicles m^{-2} (0 cm).

Number of filled grains $panicle^{-1}$

The highest number of filled grain $panicle^{-1}$ (37) was recorded for the plots treated with 80 kg N ha^{-1} (Table 3). Yesuf and Balcha (2014), Chamely *et al.,* (2015), and Zhang *et al.,* (2020) have documented that the application of nitrogen fertilizer has a notable impact on rice grains, specifically length and width. Pendimethalin 1500 g a.i. ha^{-1} + bispyribac-sodium 45 g a.i. ha^{-1} treated plots had more filled grain $panicle^{-1}$ than the other combinations (Table 3). On the other hand, the lowest number of filled grain $panicle^{-1}$ was observed from the control plots (0). $N_{80}H_5$ resulted in the most filled grain $panicle^{-1}$ (72), at the nitrogen dose of 80 kg N ha^{-1}, while $N_{60}H_0$ resulted in the lowest number of filled grain $panicle^{-1}$ (0).

1000-grain weight

The 1000-grain weight (g) was significantly affected by nitrogen rates. The highest number of 1000-grain weight (17.89 g) was recorded from 80 kg N ha^{-1} pendimethalin 1500 g a.i. ha^{-1} + bispyribac-sodium 45 g a.i. ha^{-1} treated plots, which had more 1000-grain weight

than the other combinations (Table 3). The 1000-grain weight (g) was higher in the herbicide-treated plots than in the weedy check plots and gave the highest (23.67 g) from treatment H_5. The result of pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1} (H_4) was also similar to H_5 (22.33 g).

Table 3. Effect of nitrogen rates and pre and post-emergence herbicides rates on yield contributing parameters of var. BRRI dhan98 under DSR system

Treatments	Panicle m^{-2} (No.)	Panicle length (cm)	Filled grains $panicle^{-1}$ (No.)	1000-grain weight (g)
Nitrogen levels				
N_{60}	151 b	12.23	29.83 b	13.94 b
N_{80}	156 a	14.87	36.78 a	17.89 a
LSD $_{(0.05)}$	2.48	1.58	3.52	0.86
CV (%)	20.76	15.83	7.37	3.78
Pendimethalin fb. Bispyribac-sodium rates				
H_0	0.00 d	0.00 d	0.00 *e*	0.00 d
H_1	210.00 b	16.29 b	29.33 c	19.50 b
H_2	42.00 c	7.00 c	9.50 d	9.17 c
H_3	206.40 b	19.11 a	26.33 c	20.83 b
H_4	212.40 ab	19.55 a	63.67 b	22.33 a
H_5	250.20 a	19.36 a	71.00 a	23.67 a
LSD $_{(0.05)}$	38.77	1.40	4.53	1.39
CV (%)	20.97	8.56	11.29	7.22
Nitrogen levels × Pendimethalin fb. Bispyribac-sodium rates				
$N_{60}H_0$	0.00 *e*	0.00 *e*	0.00 g	0.00 g
$N_{60}H_1$	200.40 bc	16.99 b-d	26.33 *e*	20.33 d*e*
$N_{60}H_2$	0.00 *e*	0.00 *e*	0.00 g	0.00 g
$N_{60}H_3$	211.20 a-c	18.72 a-c	19.67 f	19.33 d-f
$N_{60}H_4$	238.80 a-c	18.55 a-c	63.00 c	21.00 cd
$N_{60}H_5$	255.60 a	19.13 ab	70.00 ab	23.00 ab
$N_{80}H_0$	0.00 *e*	0.00 *e*	0.00 g	0.00 g
$N_{80}H_1$	219.60 a-c	15.59 cd	32.33 d*e*	18.67 *ef*
$N_{80}H_2$	84.00 d	14.00 d	19.00 f	18.33 f
$N_{80}H_3$	201.60 a-c	19.50 ab	33.00 d	22.33 bc
$N_{80}H_4$	186.00 c	20.56 a	64.33 bc	23.67 ab
$N_{80}H_5$	244.80 ab	19.59 ab	72.00 a	24.33 a
LSD $_{(0.05)}$	64.27	1.98	6.60	1.94
CV (%)	20.97	8.56	11.29	7.22

Here: N_{60}=60 kg N ha^{-1} and N_{80}=80 kg N ha^{-1}; H_0= No weeding, H_1= pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 0 g a.i. ha^{-1}; H_2= pendimethalin 0 g a.i. ha^{-1} + bispyribac-sodium 25 g a.i. ha^{-1}; H_3= pendimethalin 500 g a.i. ha^{-1} + bispyribac-sodium 15 g a.i. ha^{-1}; H_4= pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1}; H_5= pendimethalin 1500 g a.i. ha^{-1} + bispyribac-sodium 45 g a.i. ha^{-1}

On the other hand, the lowest number of panicles was observed from the control plot (0 g). Similar findings were reported by Jabran *et al.*, (2012). Pendimethalin 1500 g a.i. ha^{-1} + bispyribac-sodium 45 g a.i. ha^{-1} (H_5) resulted in the highest 1000-grain weight (g) at 80 kg N ha^{-1} (Table 3). Treatment $N_{80}H_5$ resulted in the highest 1000-grain weight (24.33 g), followed by $N_{80}H_4$ 80 kg N ha^{-1}, and the herbicide dose was pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1} (23.67 g). On the contrary, $N_{60}H_0$ resulted in the lowest 1000-grain weight (0 g).

Biological yield

The biological yield was considerably different for nitrogen doses (Fig. 1). The highest biological yield (4.60 t ha^{-1}) was recorded with 80 kg N ha^{-1}.

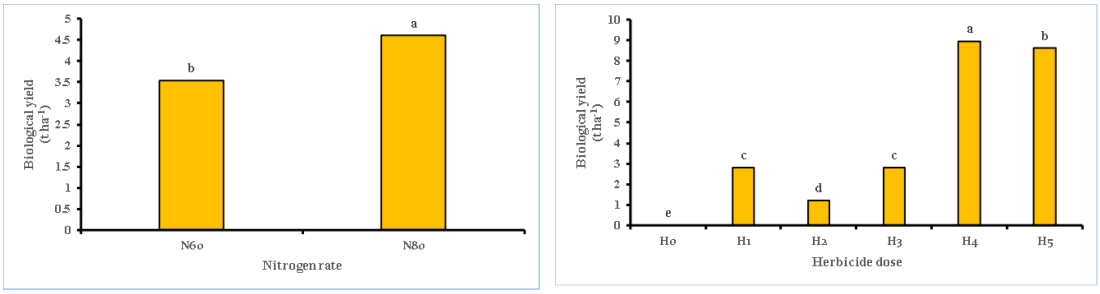

Fig. 1. Effect of nitrogen rates and pre and post-emergence herbicide doses on biological yield. Here: N_{60}=60 kg N ha^{-1} and N_{80}=80 kg N ha^{-1}; H_0= No weeding, H_1= pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 0 g a.i. ha^{-1}; H_2= pendimethalin 0 g a.i. ha^{-1} + bispyribac-sodium 25 g a.i. ha^{-1}; H_3= pendimethalin 500 g a.i. ha^{-1} + bispyribac-sodium 15 g a.i. ha^{-1}; H_4= pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1}; H_5= pendimethalin 1500 g a.i. ha^{-1} + bispyribac-sodium 45 g a.i. ha^{-1}.

The biological yield significantly differed due to the herbicide application, where pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1} treated plots had more biological yield (t ha^{-1}) than the other combinations (Fig. 2).

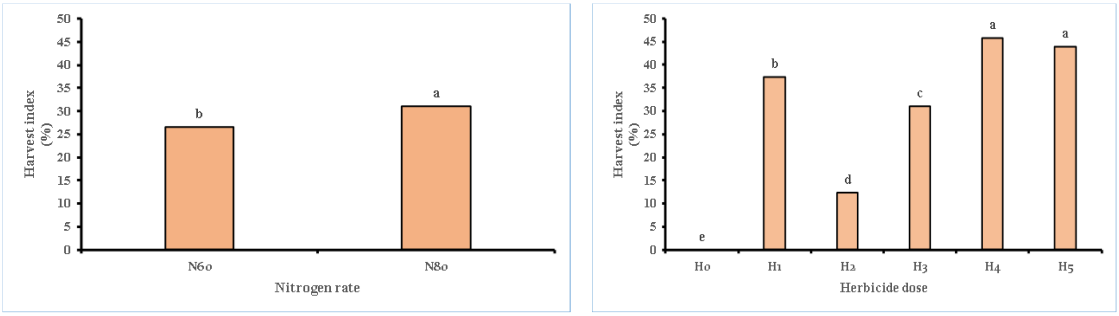

Fig. 2. Effect of nitrogen rates and pre and post-emergence herbicide doses on harvest index (%). Here: N_{60}=60 kg N ha^{-1} and N_{80}=80 kg N ha^{-1}; H_0= No weeding, H_1= pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 0 g a.i. ha^{-1}; H_2= pendimethalin 0 g a.i. ha^{-1} + bispyribac-sodium 25 g a.i. ha^{-1}; H_3= pendimethalin 500 g a.i. ha^{-1} + bispyribac-sodium 15 g a.i. ha^{-1}; H_4= pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1}; H_5= pendimethalin 1500 g a.i. ha^{-1} + bispyribac-sodium 45 g a.i. ha^{-1}

The biological yield (8.94 t ha^{-1}) was higher in the herbicide-treated plots than in the weedy check plots. On the other hand, the lowest biological yield (t ha^{-1}) was where weeding was not performed (0 t ha^{-1}). Hasanuzzaman *et al.,* (2008) corroborate the findings that the

efficacy of the herbicidal interventions impacted the biological yield. Pendimethalin 1000 g ai ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1} (H_4) resulted in the highest biological yield of 80 kg N ha^{-1} (Table 4). Treatment $N_{80}H_4$ resulted in the highest biological yield (9.41 t ha^{-1}) where $N_{60}H_0$ resulted in the lowest biological yield (0 t ha^{-1}).

Harvest Index

The harvest index (%) was considerably different for nitrogen doses (Fig. 2). The highest harvest index (31.06%) was recorded with 80 kg N ha^{-1}. The harvest index (%) significantly differed due to the herbicide application. Pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1} treated plots had more harvest index (%) than the other combinations (Table 4 and Fig. 3). The harvest index (45.76%) was higher in the herbicide-treated plots than in the weedy check plots, followed by (H_4). On the other hand, the lowest harvest index (%) was observed where weeding was not performed (0%). Pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1} (H_4) resulted in the highest harvest index (47.74%). at 80 kg N ha^{-1} (Table 4). On the other hand, $N_{60}H_0$ resulted lowest harvest index (0%).

Table 4. Effect of nitrogen rates and pre and post-emergence herbicide rates on the yield of var. BRRI dhan98 under the DSR system

Treatments	Biological yield (t ha^{-1})	Harvest index(%)
$N_{60}H_0$	0.00 f	0.00 g
$N_{60}H_1$	2.32 *e*	39.28 c
$N_{60}H_2$	0.0 f	0.00 g
$N_{60}H_3$	2.10 *e*	28.21 *e*
$N_{60}H_4$	8.48 c	43.77 b
$N_{60}H_5$	8.26 c	42.39 b
$N_{80}H_0$	0.00 f	0.00 g
$N_{80}H_1$	3.27 d	35.59 d
$N_{80}H_2$	2.42 *e*	24.60 f
$N_{80}H_3$	3.52 d	33.86 d
$N_{80}H_4$	9.41 a	47.74 a
$N_{80}H_5$	8.94 b	44.57 ab
$LSD_{(0.05)}$	0.43	3.43
CV (%)	6.02	6.30

Here: N_{60}=60 kg N ha^{-1} and N_{80}=80 kg N ha^{-1}; H_0= No weeding, H_1= pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 0 g a.i. ha^{-1}; H_2= pendimethalin 0 g a.i. ha^{-1} + bispyribac-sodium 25 g a.i. ha^{-1}; H_3= pendimethalin 500 g a.i. ha^{-1} + bispyribac-sodium 15 g a.i. ha^{-1}; H_4= pendimethalin 1000 g a.i. ha^{-1} + bispyribac-sodium 30 g a.i. ha^{-1}; H_5= pendimethalin 1500 g a.i. ha^{-1} + bispyribac-sodium 45 g a.i. ha^{-1}

Conclusion

The findings of this study showed that overall growth and crop production properties were significantly enhanced with fertilizer application of 80 kg N ha^{-1}.Moreover, weed control was found effective when pendimethalin @ 1500 g a.i. ha^{-1} in combination with bispyribac-sodium @ 45 g a.i. ha^{-1} was applied. These findings have also resulted in an enhanced yield of DSR, as well as being effectively employed for weed management in direct-seeded *Aus* rice of var. BRRI dhan98.

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