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EFFECT OF NITROGEN DOSES IN BORO RICE GROWN WITH VARIABLE LEVELS OF FLOATING DUCKWEED

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Abstract

An experiment was carried out at the Agronomy Research Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2018 to June 2019 to study the nitrogen requirement of boro rice grown with floating duckweed. The experiment was laid out in a Factorial Randomized Complete Block Design with three replications. The treatments were duckweed: *viz.* D_0 = Control (0 g duckweeds m^{-2}), D_1 = 200 g duckweeds m^{-2}, D_2 = 400 g duckweeds m^{-2} and D_3 = 600 g duckweeds m^{-2}) and nitrogen treatment: N_1 = 45 kg N ha^{-1}, N_2 = 90 kg N ha^{-1} and N_3 = 180 kg N ha^{-1}). Different doses of duckweeds showed significant influence on most of the parameters of which D_2 (400 g duckweeds m^{-2}) treatment the best performance on growth and yield parameters of rice. Among different doses of nitrogen, N_2 (90 kg N ha^{-1}) gave the best results on growth and yield parameters of rice. In case of combined effect, D_2N_2 showed the highest number of tillers $hill^{-1}$ (16.40), dry weight $hill^{-1}$ (48.97 g), number of effective tillers $hill^{-1}$ (14.73) and number of grains $panicle^{-1}$ (189.50). This treatment combination also showed the highest number of filled grains $panicle^{-1}$ (183.90), panicle length (25.83 cm), 1000 -grain weight (25.13 g), seed yield (7.24 t ha^{-1}), straw yield (8.47 t ha^{-1}), biological yield (15.71 t ha^{-1}) and harvest index (46.09%). On the other hand, D_0N_3 gave the least results on these parameters. Findings revealed that application of 400 g duckweeds m^{-2} with 90 kg N ha^{-1} showed the superiority over other treatment combinations to produce higher grain yield of boro rice.

Introduction

Globally, agriculture is currently facing unprecedented challenges for nourishing the increasing population without devastating the environment (Chen *et al.*, 2014; Zhang *et al.*, 2015). In Bangladesh, area covered by rice was 11.39 million hectares with the production of 35.05 million metric tons (BBS, 2018). Boro rice is one of the most important rice crops for Bangladesh with respect to its high yield and contribution to rice production. Nitrogen is a major essential plant nutrient and a key input for increasing crop yield. Rice plants require a large amount of nitrogen at the early and mid tillering stage to maximize the number of panicles. Optimum dose of nitrogen fertilization plays a vital role in growth and development of rice plant. Rice grain yield was recorded significantly highest between ranges of 90-250 kg ha^{-1} nitrogen application (Marazi *et al.*, 1993; Daniel and Wahab, 1994; Bali *et al.*, 1995). A significant increase in tillering (Hussain *et al.*, 1989; Meena *et al.*, 2003) with increase in nitrogen supply was observed. GM is generally eco-friendly, economically viable and renewable for sustainable agriculture.

Over the last 40 years, research regarding duckweed mainly focused on phytoremediation and nutrient recovery from wastewater and for animal feedstock and the production of biofuels, due to its high growth rate, high biomass yield, excellent nutrient uptake ability, and tolerance to high nutrient levels (Cheng *et al.*, 2002; Mohedano *et al.*, 2012). So far, few studies have examined the influence of duckweed on NH_3 volatilization (Zimmo *et al.*, 2003; Li *et al.*, 2009; Sun *et al.*, 2015), and only Li *et al.* (2009) reported that duckweed cover combined with urea could effectively increase rice yield at 90 and 180 kg N ha ^{1}. Meanwhile, the current Chinese agriculture systems are highly fertilized, few studies have comprehensively accessed the N balance of urea combined with duckweed in current intensive rice cropping systems. Therefore, a field experiment was conducted with the aims to increasing N use efficiency with floating duckweed on boro rice yield.

Materials and Methods

The experiment was carried out at Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh during the period from November 2018 to June 2019. The geographical location of the site is 90°33′E longitude and 23°77′N latitude which belongs to "The Modhupur Tract", AEZ-28. The experiment was laid out in Factorial Randomized Complete Block Design (RCBD) with three replications. The experiment was comprised of duckweed at four levels, D_0 = Control (0 g duckweeds m^{-2}), D_1 = 200 g duckweeds m^{-2}, D_2 = 400 g duckweeds m^{-2} and D_3 = 600 g duckweeds m^{-2}, and nitrogen at three levels, N_1 = 45 kg N ha^{-1}, N_2 = 90 kg N ha^{-1} and N_3 = 180 kg N ha^{-1}. Healthy seeds of boro rice var. BRRI dhan28 was used as test crop. After final preparation of land with recommended fertilizer dose, 40 days old seedlings with 25 cm × 15 cm spacing was maintained. After collection of duckweeds from sources those were kept in a cistern in research field for purification and refreshing. When field was ready then measured in several packets previously determined weight after water removal. Duckweeds were introduced in the target plots after two days of planting seedlings. Water level of plots maintained in below plots ridges to control duckweeds in desired plots. All intercultural and plant protection measures were taken to all the plots. The first plant height and number of tillers hill^{-1} were measured at 25 DAT and continued up to harvest with 20 days interval. Data on yield components were collected from the sample plants of each plot. The significant differences among the treatments were judged at 5% level of probability by using Least Significant Difference (LSD) with a computer operated program named MSTAT-C.

Results and Discussion

Plant height

Significant difference was found among the treatment on plant height of rice at all growth stages due to application of duckweed at different rates, different doses nitrogen and its combination (Table 1). Results revealed that the maximum plant height (23.19, 61.41 and 97.49 cm at 30, 60 DAT and at harvest, respectively) was found from the treatment D_2 which was statistically same with D_1 at 60 DAT but at harvest it was significantly different from other treatments. The lowest plant height (20.28, 52.82 and cm at 30, 60 DAT and at harvest, respectively) was found from control treatment D_0. The maximum plant height (23.06, 60.69 and 97.28 cm at 30, 60 DAT and at harvest, respectively) was found from the treatment N_3 which was statistically similar with N_2 whereas the lowest plant height (20.21, 54.68 and 89.14 cm at 30, 60 DAT and at harvest, respectively) was found from the treatment N_1. The result obtained from the present study was followed by the findings of Adhikari (2018) and Chamely and Islam (2015). The highest plant height (24.43, 63.99 and 100.90 cm at 30, 60 DAT and at harvest, respectively) was found from the treatment combination of D_2N_3 whereas the lowest plant height (21.77, 55.59 and 92.73 cm at 30, 60 DAT and at harvest, respectively) from the treatment combination of D_0N_1.

Table 1. Plant height and number of tillers hill^{-1} of rice as influenced by duckweed and nitrogen and their combination

Treatments	Plant height (cm)			Number of tillers hill^{-1}		
	30 DAT	60 DAT	At harvest	30 DAT	60 DAT	At harvest
Effect of duckweed (D)						
D_0	20.28 b	52.82 d	88.35 c	6.256 c	10.03 b	10.81 c
D_1	22.12 ab	59.78 a	94.29 b	7.333 b	13.09 a	14.44 ab
D_2	23.19 a	61.41 a	97.49 a	9.289 a	14.16 a	14.76 a
D_3	21.16 ab	56.78 c	92.86 b	6.978 bc	10.95 b	13.06 b
$LSD_{(0.05)}$	2.41	2.30	1.87	0.92	1.40	1.50
Effect of nitrogen (N)						
N_1	20.21 b	54.68 b	89.14 b	7.125	11.91 b	13.06 b
N_2	21.80 ab	57.72 ab	93.32 ab	7.875	13.60 a	14.89 a
N_3	23.06 a	60.69 a	97.28 a	7.392	10.66 c	11.85 b
$LSD_{(0.05)}$	2.08	5.45	7.92	NS	1.22	1.30
Combined effect of duckweed and nitrogen						
D_0N_1	21.77 a-c	55.59 a-c	92.73 ab	6.00 e	9.913 e-g	10.22 de
D_0N_2	19.94 bc	52.80 bc	88.30 ab	6.87 de	10.93d-g	12.41 b-d
D_0N_3	19.14 c	50.08 c	84.03 b	5.90 e	9.253 g	9.800 e
D_1N_1	22.18 a-c	60.67 a-c	94.77 ab	6.20 de	13.07b-d	14.27 ab
D_1N_2	23.21 a-c	62.43 ab	98.11 ab	6.60 de	14.40 ab	15.99 a
D_1N_3	20.96 a-c	56.23 a-c	89.98 ab	9.20 bc	11.80 c-f	13.07 bc
D_2N_1	23.63 ab	61.46 ab	96.59 ab	9.77 b	14.19 a-c	14.54 ab
D_2N_2	21.49 a-c	58.79 a-c	94.93 ab	11.43 a	16.17 a	16.40 a
D_2N_3	24.43 a	63.99 a	100.9 a	6.67 de	12.13 b-e	13.33 bc
D_3N_1	21.43 a-c	55.97 a-c	93.62 ab	6.53 de	10.47 e-g	13.20 bc
D_3N_2	22.81 a-c	60.73 a-c	97.33 ab	6.60 de	12.91 -d	14.76 ab
D_3N_3	19.24 c	53.63 a-c	87.63 ab	7.80 cd	9.46 fg	11.21 c-e
$LSD_{(0.05)}$	4.17	10.90	15.83	1.60	2.43	2.59
CV (%)	11.35	11.16	10.03	12.67	11.90	11.53

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

D_0 = Control (0 g duckweeds m^{-2}), D_1 = 200 g duckweeds m^{-2}, D_2 = 400 g duckweeds m^{-2}, D_3 = 600 g duckweeds m^{-2}, N_1 = 45 kg N ha^{-1}, N_2 = 90 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

Number of tillers hill^{-1}

Significant effect was found on number of tillers hill^{-1} of rice among the treatment at all growth stages due to application of duckweed at different rates, different doses nitrogen and its combination (Table 1). Results revealed that the maximum number of tillers hill^{-1} (9.29, 14.16 and 14.76 at 30, 60 DAT and at harvest, respectively) was found from the treatment D_2 which was statistically similar with D_1 at 60 DAT and at harvest whereas the lowest number of tillers hill^{-1} (6.26, 10.03 and 10.81 at 30, 60 DAT and at harvest, respectively) from control treatment D_0. The highest number of tillers hill^{-1} (7.88, 13.60 and 14.89 at 30, 60 DAT and at harvest, respectively) was found from the treatment N_2 which was significantly different from other treatments. The lower number of tillers hill^{-1} (7.39, 10.66 and 11.85 at 30, 60 DAT and at harvest, respectively) was found from the treatment N_3 which was statistically identical with N_1. More or less similar result was also observed by Karim (2019), Adhikari (2018) and Chamely and Islam (2015) also found that N had significant effect on number of tillers hill^{-1}. The maximum number of tillers hill^{-1} (11.43, 16.17 and 16.40 at 30, 60 DAT and at harvest, respectively) was found from the treatment combination of D_2N_2 which was statistically similar with the treatment combination of D_1N_1, D_1N_2, D_2N_1 and D_3N_2. The lowest number of tillers hill^{-1} (5.90, 9.25 and 9.80 at 30, 60 DAT and at harvest, respectively) was found from the treatment combination of D_0N_3 which was statistically similar with the treatment combination of D_0N_1 and D_3N_3.

Number of non-effective tillers hill^{-1}

Significant effect was found on number of non-effective tillers hill^{-1} of rice among the treatment due to application of duckweed at different rates, different doses nitrogen and its combination (Table 2). The highest number of non-effective tillers hill^{-1} (4.25) was found from control treatment D_0 which was significantly different from other treatments. The lowest number of non-effective tillers hill^{-1} (1.76) was found from the treatment D_2. The highest number of non-effective tillers hill^{-1} (3.45) was found from the treatment N_3while lower number of non-effective tillers hill^{-1} (2.26) was found from the treatment N_2 followed by N_1. The result obtained from the present study was followed with the findings of Karim (2019) and Adhikari (2018). In treatment combinations, lower number of non-effective tillers hill^{-1} (1.40) was found from D_2N_2 which was statistically similar with D_1N_2 and D_2N_1.

Effective tillers hill^{-1}

Number of effective tillers hill^{-1} of rice among the treatment was found significant due to application of duckweed at different rates, different doses nitrogen and its combination (Table 2). The maximum number of effective tillers hill^{-1}(13.02) was found from the treatment D_2 followed by D_1 whereas the lowest number of effective tillers hill^{-1} (7.41) from control treatment D_0. Higher number of effective tillers hill^{-1} (11.67) was found from the treatment N_2 followed by N_1 whereas the lowest number of effective tillers hill^{-1} (8.97) from N_3. Karim (2019) and Chamely and Islam (2015) also found significant effect of N on number of effective tillers hill^{-1} of rice which supported the present study. Higher number of effective tillers hill^{-1} (14.73) was found from the treatment combination of D_2N_2 which was statistically similar with D_1N_2 whereas the lowest number of effective tillers hill^{-1} (6.40) was found from the treatment combination of D_0N_3 which was statistically similar with D_0N_1 and D_3N_3.

Number of grains panicle^{-1}

Number of grains panicle^{-1} of rice among the treatment due to application of duckweed at different rates, different doses nitrogen and its combination were found significant (Table 2). Higher number of grains panicle^{-1} (179.40) was foun from the treatment D_2 which was statistically identical with D_1 whereas the lowest number of grains panicle^{-1} (132.60) from control treatment D_0. The maximum number of grains panicle^{-1} (169.70) was found from the treatment N_2 which was statistically similar with N_1 whereas the lowest number of grains panicle^{-1} (149.80) from the treatment N_3. The result obtained from the present study was corroborates with the findings of Karim (2019), Adhikari (2018) and Chamely and Islam (2015). The maximum number of grains panicle^{-1} (189.50) was found from the treatment combination of D_2N_2 which was statistically similar with the treatment combination of D_1N_1, D_1N_2, D_2N_1, D_2N_3 and D_3N_2. The lowest number of grains panicle^{-1} (121.50) was found from the treatment combination of D_0N_3 which was statistically similar with D_0N_1, D_0N_2 and D_3N_3.

Number of filled grains panicle^{-1}

Significant variation was found on number of filled grains panicle^{-1} of rice among the treatment due to application of duckweed at different rates, different doses nitrogen and its combination (Table 2). The maximum number of filled grains panicle^{-1} (170.00) was found from the treatment D_2 which was statistically identical with D_1 whereas the lowest number of filled grains panicle^{-1} (110.10) from control treatment D_0. The highest number of filled grains panicle^{-1} (156.60) was found from the treatment N_2 whereas the lower number of filled grains panicle^{-1} (129.30) from the treatment N_3 which was statistically identical with N_1. Similar result was also observed by Chamely and Islam (2015) and Adhikari (2018). The maximum number of filled grains panicle^{-1} (183.90) was found from the treatment combination of D_2N_2 which was statistically similar with the treatment combination of D_1N_2, D_2N_1 and D_2N_3. Lower number of filled grains panicle^{-1} (93.18) was found from the treatment combination of D_0N_3 which was statistically similar with the treatment combination of D_0N_1.

Number of unfilled grains panicle^{-1}

Statistically significant variation was found on number of unfilled grains panicle^{-1} of rice among the treatment due to application of duckweed at different rates, different doses nitrogen and its combination (Table 2). The highest number of unfilled grains panicle^{-1} (22.53) was found from control treatment D_0. The lowest number of unfilled grains panicle^{-1} (9.35) was found from the treatment D_2 which was significantly different from other treatments. Chamely and Islam (2015) also found similar result with the present study. The lowest number of unfilled grains panicle^{-1} (13.08) was found from the treatment N_2 whereas higher number of unfilled grains panicle^{-1} (20.51) was found from the treatment N_3 followed by N_1. The lowest number of unfilled grains panicle^{-1} (5.62) was found from the treatment combination of D_2N_2 which was significantly different from other treatment combinations whereas the maximum number of unfilled grains panicle^{-1} (28.29) was found from the treatment combination of D_0N_3 followed by D_0N_1 and D_3N_3.

Table 2. Yield contributing parameters of rice as influenced by duckweed and nitrogen and also their combination

Treatments	Yield contributing parameters						
	No. of non-effective tillers hill^{-1}	**No. of effective tillers hill^{-1}**	**No. of grains panicle^{-1}**	**No. of filled grains panicle^{-1}**	**No. of unfilled grains panicle^{-1}**	**Panicle length (cm)**	**1000-grain weight (g)**
Effect of duckweed (D)							
D_0	4.25 a	7.41 d	132.6 c	110.1 c	22.53 a	18.89 c	20.94 b
D_1	2.40 c	11.87 b	171.6 a	155.7 a	15.81c	23.48 a	23.05 ab
D_2	1.76 d	13.02 a	179.4 a	170.0 a	9.35 d	24.58 a	24.49 a
D_3	3.11 b	8.58 c	152.8 b	133.5 b	19.30 b	21.29 b	22.31 b
$LSD_{(0.05)}$	0.31	1.05	16.89	15.34	1.73	2.07	2.13
Effect of nitrogen (N)							
N_1	2.93 b	10.02 b	157.7 ab	141.1 b	16.65 b	22.01 ab	22.88 ab
N_2	2.26 c	11.67 a	169.7 a	156.6 a	13.08 c	23.29 a	23.82 a
N_3	3.45 a	8.972 c	149.8 b	129.3 b	20.51 a	20.88 b	21.40 b
$LSD_{(0.05)}$	0.27	0.91	14.62	13.28	1.49	1.80	1.84
Combined effect of duckweed and nitrogen							
D_0N_1	4.53 a	7.57 fg	131.1 de	108.8 ef	22.26 b	18.90 ef	21.40b-d
D_0N_2	3.43 bc	8.25 ef	145.3 c-e	128.3 de	17.03 cd	20.61 c-f	22.07a-d
D_0N_3	4.80 a	6.40 g	121.5 e	93.18 f	28.29 a	17.17 f	19.37 d
D_1N_1	2.47 e	11.30 cd	170.7 a-c	155.0 bc	15.69 de	23.73a-d	23.03a-d
D_1N_2	1.53 g	13.80 ab	180.2 ab	167.4 ab	12.79 e	24.55 ab	24.45 a-c
D_1N_3	3.20 b-d	10.52 d	163.7 a-c	144.8b-d	18.96 c	22.15b-e	21.67a-d
D_2N_1	1.67 fg	12.80 bc	178.1 ab	168.4 ab	9.723 f	24.15 a-c	24.67 ab
D_2N_2	1.40 g	14.73 a	189.5 a	183.9 a	5.623 g	25.83 a	25.13 a
D_2N_3	2.20 ef	11.53 cd	170.4 a-c	157.7 a-c	12.71 e	23.75a-d	23.67 a-c
D_3N_1	3.03 cd	8.42 ef	151.0b-d	132.1 c-e	18.94 c	21.27b-e	22.40a-d
D_3N_2	2.67 de	9.89 de	163.7 a-c	146.8b-d	16.86 cd	22.17b-e	23.63 a-c
D_3N_3	3.62 b	7.44 fg	143.7 c-e	121.6 de	22.09 b	20.43 d-f	20.91 cd
$LSD_{(0.05)}$	0.54	1.82	29.25	26.57	2.99	3.59	3.69
CV (%)	11.13	10.49	10.86	11.02	10.53	9.62	9.59

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

D_0 = Control (0 g duckweeds m^{-2}), D_1 = 200 g duckweeds m^{-2}, D_2 = 400 g duckweeds m^{-2}, D_3 = 600 g duckweeds m^{-2},
N_1 = 45 kg N ha^{-1}, N_2 = 90 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

Panicle length

Panicle length of rice among the treatment due to application of duckweed at different rates, different doses nitrogen and its combination was found significant variation (Table 2). The maximum panicle length (24.58 cm) was found from the treatment D_2 which was statistically identical with D_1 whereas the lowest panicle length (18.89 cm) from control treatment D_0. The maximum panicle length (23.29 cm) was found from the treatment N_2 which was statistically similar with N_1 whereas the lowest panicle length (20.88 cm) from the treatment N_3. The maximum panicle length (25.83 cm) was found from the treatment combination of D_2N_2 which was statistically similar with the treatment combination of D_1N_1, D_1N_2, D_2N_1 and D_2N_3. The lowest panicle length (17.17 cm) was found from the treatment combination of D_0N_3 which was statistically similar with the treatment combination of D_0N_1, D_0N_2 and D_3N_3.

Weight of 1000 grain

Significant variation was found on 1000- grain weight of rice among the treatment due to application of duckweed at different rates, different doses nitrogen and its combination (Table 2). The maximum 1000- grain weight (24.49 g) was found from D_2 which was statistically similar with D_1 whereas the lowest 1000- grain weight (20.94 g) was found from control treatment D_0 which was statistically identical with D_3. The maximum 1000- grain weight (23.82 g) was found from the treatment N_2 which was statistically similar with N_1 whereas the lowest 1000 grain weight (21.40 g) from the treatment N_3. The result obtained from the present study was following with the findings of Chamely and Islam (2015). The maximum 1000- grain weight (25.13 g) was found from the treatment combination of D_2N_2 which was statistically similar with the treatment combination of D_0N_2, D_1N_1, D_1N_2, D_1N_3, D_2N_1, D_2N_3, D_3N_1 and D_3N_2. The lowest 1000- grain weight (19.34 g) was found from the treatment combination of D_0N_3 which was statistically similar with the treatment combination of D_0N_1 and D_3N_3.

Grain yield

Significant effect was found on seed yield of rice among the treatment due to application of duckweed at different rates, different doses nitrogen and its combination (Table 3). Higher grain yield (6.24 t ha^{-1}) was found from the treatment D_2 which was statistically identical with D_1 whereas the lowest grain yield (3.87 t ha^{-1}) was found from control treatment D_0. The maximum grain yield (6.08 t ha^{-1}) was found from the treatment N_2 which was followed by N_1. The lowest grain yield (4.39 t ha^{-1}) was found from the treatment N_3 which was significantly different from other treatments. Gewaily and Adel (2018) was also found a linear increase in grain yield with continuous rate increase of nitrogen from 0 to 220 kg ha^{-1}. The maximum grain yield (7.24 t ha^{-1}) was found from the treatment combination of D_2N_2 which was statistically similar with D_1N_2. The lowest seed yield (3.40 t ha^{-1}) was found from the treatment combination of D_0N_3 which was statistically similar with the treatment combination of D_0N_1, D_3N_1 and D_3N_3. The result obtained on seed yield of rice was conformity with the findings of Yao and Zhang (2017) that increased N use efficiency with duckweed and also found that rice cultivation using urea combined with duckweed achieved higher rice yield by 9–10%.

Straw yield

Significant effect was found on straw yield of rice among the treatment due to application of duckweed at different rates, different doses nitrogen and its combination (Table 3). The maximum straw yield (7.71 t ha^{-1}) was found from the treatment D_2 which was statistically similar with D_1 whereas the lowest straw yield (6.60 t ha^{-1}) was found from control treatment D_0. The highest straw yield (7.77 t ha^{-1}) was found from the treatment N_2 which was significantly different from other treatments.

Biological yield

Significant effect was found on biological yield of rice among the treatment due to application of duckweed at different rates, different doses nitrogen and its combination (Table 3). The maximum biological yield (13.64 t ha^{-1}) was found from the treatment D_2 which was statistically identical with D_1. The lowest biological yield (10.47 t ha^{-1}) was found from control treatment D_0 which was statistically identical with D_3. The highest biological yield (13.84 t ha^{-1}) was found from the treatment N_2 which was significantly different from other treatments. The lowest biological yield (11.92 t ha^{-1}) was obtained from the treatment N_3 which was statistically identical with N_1. Chamely and Islam (2015) and Karim (2019) also found similar result with the present study. The maximum biological yield (15.71 t ha^{-1}) was found from the treatment combination of D_2N_2 which was statistically similar with the treatment combination of D_1N_2 and D_2N_1. The lowest biological yield (9.51 t ha^{-1}) was found from the treatment combination of D_0N_3 which was statistically similar with the treatment combination of D_0N_1.

Table 3. Yield parameters of rice as influenced by duckweed and nitrogen and their combination

Treatments	Yield parameters			
	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Effect of duckweed (D)				
D_0	3.87 c	6.60 b	10.47 b	36.90 b
D_1	5.89 a	7.27 ab	13.05 a	44.54 a
D_2	6.24 a	7.71 a	13.94 a	44.61 a
D_3	4.64 b	6.85 b	11.50 b	40.16 ab
$LSD_{(0.05)}$	0.61	0.69	1.30	4.46
Effect of nitrogen (N)				
N_1	5.01 b	6.99 b	11.92 b	41.34
N_2	6.08 a	7.77 a	13.84 a	43.52
N_3	4.39 c	6.57 b	10.96 b	39.80
$LSD_{(0.05)}$	0.53	0.60	1.13	NS
Combined effect of duckweed and nitrogen				
D_0N_1	3.75 gh	6.46 cd	10.21 fg	36.76 c
D_0N_2	4.46 efg	7.24 b-d	11.70 c-g	38.09 bc
D_0N_3	3.40 h	6.10 d	9.51 g	35.84 c
D_1N_1	5.84 cd	7.17 b-d	12.68 c-e	44.83 ab
D_1N_2	6.95 ab	8.02 ab	14.97 ab	46.39 a
D_1N_3	4.87 d-f	6.63 cd	11.51 c-g	42.41 a-c
D_2N_1	6.16 bc	7.55 a-c	13.71 a-c	44.94 ab
D_2N_2	7.24 a	8.47 a	15.71 a	46.09 a
D_2N_3	5.31 c-e	7.10 b-d	12.41 c-f	42.82 a-c
D_3N_1	4.30 e-h	6.76 cd	11.07 d-g	38.83 a-c
D_3N_2	5.65 cd	7.34 a-c	13.00 b-d	43.52 a-c
D_3N_3	3.98 f-h	6.45 cd	10.43 e-g	38.12 bc
$LSD_{(0.05)}$	1.06	1.20	2.25	7.72
CV (%)	12.09	9.93	10.87	10.98

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

D_0 = Control (0 g duckweeds m^{-2}), D_1 = 200 g duckweeds m^{-2}, D_2 = 400 g duckweeds m^{-2}, D_3 = 600 g duckweeds m^{-2}, N_1 = 45 kg N ha^{-1}, N_2 = 90 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

Lower straw yield (6.57 t ha^{-1}) was found from the treatment N_3 which was statistically identical with N_1. The maximum straw yield (8.47 t ha^{-1}) was found from the treatment combination of D_2N_2 which was statistically similar with the treatment combination of D_1N_2, D_2N_1 and D_3N_2. Lower straw yield (6.10 t ha^{-1}) was found from the treatment combination of D_0N_3 which was statistically similar with the treatment combination of D_0N_1, D_1N_3, D_3N_1 and D_3N_3.

Harvest index

Significant effect was found on harvest index of rice among the treatment due to application of duckweed and combined effect of duckweed and nitrogen, but non-significant in nitrogen application at different doses (Table 3). Higher harvest index (44.61%) was found from the treatment D_2 which was statistically similar with D_1 and D_2 whereas the lowest harvest index (36.90%) from control treatment D_0. The highest harvest index (43.52%) was found from the treatment N_2 whereas the lowest harvest index (39.80%) from N_3. Karim (2019) and Chamely and Islam (2015) was also found similar result. The maximum harvest index (46.09%) was found from the treatment combination of D_2N_2 which was statistically identical with the treatment combination of D_1N_2. Treatment combinations, D_1N_1 and D_2N_1 were similar with D_2N_2. The lowest harvest index (35.84%) was found from the treatment combination of D_0N_3 which was statistically identical with D_0N_1.

Conclusion

Considering the above results, it may be concluded that (400 g duckweeds m^{-2}) application showed the superiority over other treatments to produce higher grain yield of rice. Nitrogen (90 kg N ha^{-1}) application showed higher rice yield over other nitrogen treatments. Application of 400 g duckweeds m^{-2} with 90 kg N ha^{-1} performed the best among the treatments. The trial is confined in one location with one season resulr so, more research is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performances.

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