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Growth, Yield and Profitability of Cabbage (*Brassica oleracea* L.) as Influenced by Applied Nitrogen and Plant Spacing

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Abstract

An experiment was conducted with cabbage during October 2012 to February 2013 at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Four levels of nitrogen: viz. 0, 150, 250 and 350 kg ha^{-1} and three plant spacings: 50 x 30, 50 x 40 and 50 x 50 cm were applied in a Randomized Complete Block Design with three replications. Nitrogen @ 250 kg ha^{-1} with the spacing of 50 x 50 cm was more effective and produced the highest fresh weight of head (2.17 kg), marketable head yield (86.93 t ha^{-1}). This treatment was also more profitable than the rest of the treatments, while the lowest profit was in N_0S_1.

Keywords: Cabbage, *Brassica oleracea*, profitability, nitrogen, plant spacing

1. Introduction

Cabbage (*Brassica oleracea* L.) is an important leafy vegetable belonging to the family Cruciferae. It is herbaceous biennial and extensively grown in Bangladesh during winter. It is a rich source of vitamins A and C and may be served in slaw, salads or cooked dishes (Andersen, 2000 and Tiwari *et al*., 2003). In Bangladesh, the crop is cultivated in 16.6 thousand hectares with a production of 220 thousand metric tons and the average yield is about 9 t ha^{-1} (BBS, 2010) which is low compared to other cabbage growing countries. To improve its production, some factors e.g. application of adequate fertilizers and optimum plant population are to be provided (Kumar and Rawat, 2002). Adequate nitrogen promotes vigorous vegetative growth. It is also important in the formation of chlorophyll and a component of proteins. Lack of nitrogen causes slow, spindly growth and pale foliage, resulting in limited production (Hadfield, 1995). On the other hand, spacing is another vital factor that was reported to have a great influence on cabbage production. Yield contributing characteristics are highly affected by higher spacing and becomes less if spacing between plants are decreased (Ullah *et al*., 2013). Therefore, nitrogen and spacing levels may have positive influences on the cabbage head. This study was therefore, under taken to evaluate the effect of nitrogen and plant spacings on growth, yield and profitability of cabbage.

2. Materials and Methods

2.1. Experimental site, soil and climate

The experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural

University, Dhaka, Bangladesh during October 2012 to February 2013. The experimental site was at 24.09° N latitude and 90.26°E longitude with an elevation of 8.20 m from the sea level. The soil was a silty loam belonging to the Modhupur Tract (AEZ-28) and subtropical climate characterized by heavy precipitation during April-September and scanty during October-March.

2.2. Planting materials and seedbed preparation

Seeds of "Autumn Queen" variety of cabbage were sown on 15 October 2012. A 3 × 2 m seedbed was well ploughed and all stubbles were removed. Well decomposed cowdung was added during the bed preparation.

2.3. Seed treatment, seed sowing and raising of seedling

Seeds were treated with Vitavax 200 WP @ 2.5 g kg^{-1} of seeds and sown in the seedbed on 15 October 2012. The bed was covered with dry rice straw to conserve soil moisture. Sowing was done thinly in lines 5 cm apart at the depth of 2 cm by hand and covered with a thin layer of soil following light watering. The watering was done till germination was completed and the cover of the dry straw was removed immediately after emergence of seedlings. Weeding and mulching were done as needed.

2.4. Treatments and design of the experiment

There were four levels of nitrogen and three spacings. The levels of nitrogen were: 0, 150, 250 and 350 kg ha^{-1} as represented by N_0, N_1, N_2 and N_3, respectively. The plant spacings were: 50 x 30, 50 x 40 and 50 x 50 cm as represented by S_1, S_2 and S_3, respectively. The experiment was laid out in a Randomized Complete Block Design with three replications. The size of each plot was 3 × 2 m and, the distance of 50 cm was maintained in between two adjacent plots and 1m between the blocks.

2.5. Land preparation and application of manure and fertilizers

The experimental field was ploughed and leveled properly by laddering. The basal doses of manure and fertilizers were applied during the final land preparation. The fertilizers: urea was applied as per treatments. However, TSP, MP and cowdung were applied @ 250, 300, 5000 kg ha^{-1}, respectively (Anonymous, 2012). Full doses of cowdung and TSP were applied during the final land preparation. The total amounts of urea and MP were applied in two instalments- the first half was at 15 and the second half at 35 days after transplanting the seedlings.

2.6. Transplanting of seedlings and intercultural operation

Healthy seedlings were selected for transplanting. Before transplanting, the roots of the seedlings were dipped in solution of Bavistin @ 2 g L^{-1} of water. The seedlings 40 days old were transplanted in the afternoon on 20 November 2012 maintaining the spacing as per the treatments. Intercultural operations like gap filling, weeding, earthing-up and irrigation were furnished for proper growth and development of the crop. Malathion 57 EC @ 2 ml L^{-1} and rovral 50 WP @ 2 g L^{-1} of water were sprayed to control mole crickets and caterpillars, and alternaria leaf spot disease, respectively.

2.7. Harvesting, data collection, statistical analyses and economic analyses

Harvesting was done on 10 February 2013 as plants formed compact heads. Data on plant growth at different dates after transplanting and yield parameters were collected at harvest, analyzed and the mean values were adjudged using the least significance difference (LSD) test. Finally, the cost of production was analyzed with the view to find out the most profitable treatment combination. The economic analyses were done with a view to observing the comparative cost and benefit under different treatment combinations. For this purpose, the input cost, (land preparation, seed cost, manures and fertilizers, intercultural operation and manpower required for all the operations from sowing to harvesting) were recorded against each treatment.

3. Results and Discussion

3.1. Plant height

Plant height varied significantly due to nitrogen (Figure 1). The tallest plants at 80 days after transplanting (37.26 cm) was found in N_3 while the shortest one in N_0. Plant height at different days after transplanting increased with 350 kg N ha^{-1}. That might be due to higher N uptake by plants possibly created favorable conditions for better growth than those of others. This result is in agreement with the findings of Pramanik (2007) where who reported that plant height increased with the increasing doses of nitrogen upto 260 kg ha^{-1}. Plant height was also increased significantly due to spacing (Figure 2). The wider spacing of 50 × 50 cm produced the tallest plant, whereas the shortest one was in 50 × 30 cm. The results show that plant height increased with the increase in spacing. That might be due to fact that the plant received sufficient light and nutrients in the wider spacing. The trend of the present results agrees to that of Khatun (2008) and Ullah *et al*. (2013). The significant variation was recorded due to combined effect of nitrogen and plant spacing too (Table 1). The tallest plant was in N_3S_3. Which was due to the receiving of sufficient amount nutrients by the plants in the widest spacing. The trends of the present results are in agreement with that of Meena (2003).

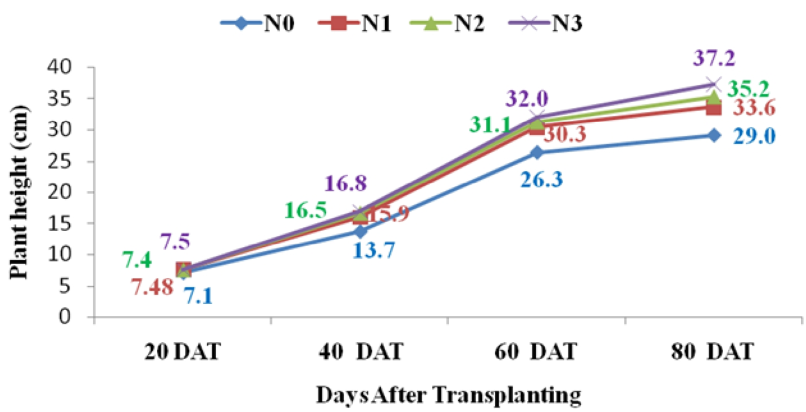

Figure 1. Effect of nitrogen on the plant height at different days after transplanting (N_0 = control, N_1 = 150, N_2 = 250 and N_3 = 350 kg N ha^{-1})

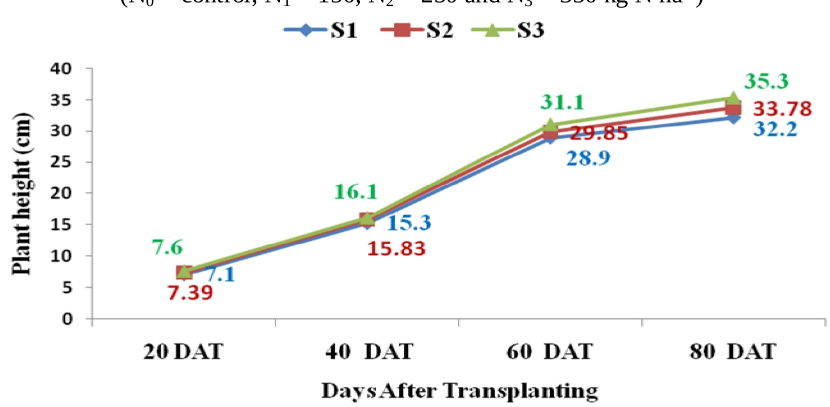

Figure 2. Effect of spacing on the plant height of cabbage at different days after transplanting (S_1 = 50 × 30, S_2 = 50 × 40 and S_3 = 50 × 50 cm)

Table 1. Interaction effects of nitrogen and plant spacing on the plant height of cabbage at different days after transplanting (DAT)

Nitrogen x Spacing	Plant height (cm) at different DAT			
	20	40	60	80
N_0S_1	6.83 d	12.93 e	25.33 h	28.03 i
N_0S_2	7.23 bcd	13.90 d	25.60 h	29.00 h
N_0S_3	7.27 bcd	14.27 d	28.13 g	30.20 g
N_1S_1	7.30 bcd	15.27 c	29.60 f	32.07 f
N_1S_2	7.60 b	16.13 bc	30.67 de	34.20 de
N_1S_3	7.60 b	16.40 ab	30.80 cde	34.67 cd
N_2S_1	7.37 bc	16.60 ab	30.07 ef	33.40 e
N_2S_2	7.53 bc	16.50 ab	31.60 bc	35.47 c
N_2S_3	7.57 bc	16.67 ab	31.80 b	36.80 b
N_3S_1	7.10 cd	16.53 ab	30.93 bcde	35.47 c
N_3S_2	7.20 bcd	16.80 ab	31.53 bcd	36.47 b
N_3S_3	8.13 a	17.27 a	33.67 a	39.83 a
LSD $_{(0.05)}$	0.48	0.95	0.92	0.94
F-test	*	*	**	**
CV (%)	3.84	3.55	1.81	1.64

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly, ns = non significant, * = significant at 5% probability, ** = significant at 1% probability, N_0 = control, N_1 = 150, N_2 = 250, N_3 = 350 kg N ha^{-1}, S_1 = 50 × 30, S_2 = 50 × 40 and S_3 = 50 × 50 cm

3.2. Number of leaves plant^{-1}

The number of leaves plant^{-1} was influenced significantly by nitrogen (Figure 3). At 80 DAT, the highest number of leaves plant^{-1} (21.29) was found with N_3. Which was due to higher amount of nutrients received by the plants in wider spacing. The present results agree with that of Meena (2003). The number of leaves plant^{-1} showed statistically significant variation except at 20 and 40 DATs (Figure 4). The maximum number of leaves plant^{-1} was found in S_3. The number of leaves plant^{-1} increased with the increase in spacing. Similar result was also reported by Meena (2003) and Ullah *et al.* (2013). The maximum numbers of leaves plant^{-1} at 80 days after transplanting was recorded from N_3S_3 while the minimum was from the N_0S_1 (Table 2).

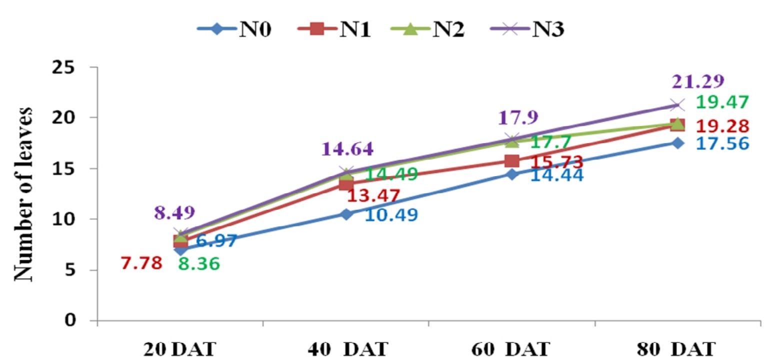

Figure 3. Effect of nitrogen on the number of leaves of cabbage at different days after transplanting (N_0 = control, N_1 = 150, N_2 = 250 and N_3 = 350 kg N ha^{-1})

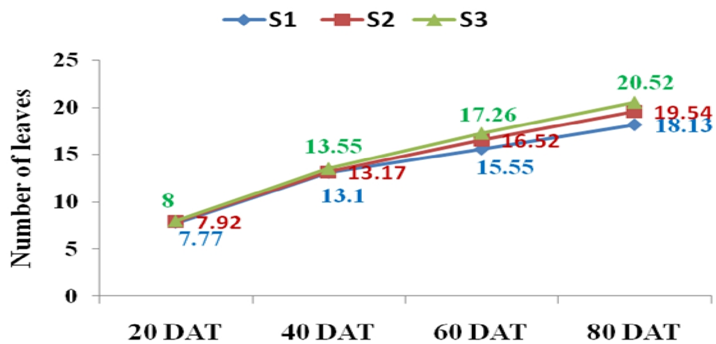

Figure 4. Effect of spacing on the number of leaves of cabbage at different days after transplanting ($S_1 = 50 \times 30$, $S_2 = 50 \times 40$ and $S_3 = 50 \times 50$ cm)

Table 2. Interaction effects of nitrogen and plant spacing on the number of leaves of cabbage at different days after transplanting (DAT)

Nitrogen x Spacing	Number of leaves at different DAT			
	20	40	60	80
N_0S_1	6.73 e	10.33 ef	13.73 g	17.40 e
N_0S_2	6.83 e	10.13 f	14.83 fg	17.83 de
N_0S_3	7.33 de	11.00 e	14.77 fg	17.43 e
N_1S_1	7.73 bcd	13.13 d	15.13 ef	18.33 cde
N_1S_2	7.93 bcd	13.60 cd	15.73 def	19.67 c
N_1S_3	7.67 cd	13.67 bcd	16.33 de	19.83 c
N_2S_1	8.33 abc	14.33 abc	16.47 d	17.47 e
N_2S_2	8.53 ab	14.47 ab	17.80 bc	19.27 cd
N_2S_3	8.20 abc	14.67 a	18.83 ab	21.67 ab
N_3S_1	8.27 abc	14.60 a	16.87 cd	19.33 cd
N_3S_2	8.40 abc	14.47 ab	17.73 bc	21.40 b
N_3S_3	8.80 a	14.87 a	19.10 a	23.13 a
$LSD_{(0.05)}$	0.82	0.85	1.24	1.53
F-test	ns	ns	ns	**
CV (%)	6.13	3.76	4.45	4.65

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly, ns = non significant, ** = significant at 1% probability, N_0 = control, N_1 = 150, N_2 = 250 and N_3 = 350 kg N ha^{-1}, $S_1 = 50 \times 30$, $S_2 = 50 \times 40$ and $S_3 = 50 \times 50$ cm

3.3. Spread of canopy

The spread of canopy was significantly higher in N_3 than other treatments whereas the minimum was in control (Table 3). The results show that higher N uptake by plants increased the length of leaf creating favorable conditions for better growth. This result is also in agreement with the findings of Pramanik (2007). The significant variation was also recorded as the combined effects of nitrogen coupled with the plant spacing. The maximum canopy was found in N_3S_3 (Table 3) because the plants received the more nutrients in the widest spacing.

Table 3. Effects of nitrogen and spacing on the spread of canopy of cabbage at different days after transplanting (DAT)

Treatment	Spread of canopy (cm) at different DAT			
	20	40	60	80
Nitrogen				
N_0	17.52 c	35.70 c	39.91 c	48.14 c
N_1	25.25 b	40.38 b	44.23 b	52.84 b
N_2	25.39 b	42.54 a	47.60 a	55.40 a
N_3	26.33 a	42.97 a	47.50 a	55.42 a
$LSD_{(0.05)}$	0.49	0.74	0.56	0.79
Spacing				
S_1	22.57 c	38.29 c	42.48 c	50.21 c
S_2	23.80 b	40.54 b	44.52 b	52.94 b
S_3	24.50 a	42.36 a	47.43 a	55.71 a
$LSD_{(0.05)}$	0.43	0.64	0.49	0.69
Nitrogen x Spacing				
N_0S_1	17.20 e	35.20 e	38.93 h	47.50 g
N_0S_2	17.64 e	35.80 e	39.30 h	47.67 g
N_0S_3	17.72 e	36.10 e	41.50 g	49.27 f
N_1S_1	23.57 d	36.47 e	40.53 g	47.47 g
N_1S_2	25.88 bc	41.07 d	44.57 f	53.73 de
N_1S_3	26.32 b	43.60 bc	47.60 c	57.33 b
N_2S_1	24.30 d	40.83 d	45.60 de	53.33 e
N_2S_2	25.75 bc	42.40 c	47.67 c	55.40 c
N_2S_3	26.11 b	44.40 ab	49.53 b	57.47 ab
N_3S_1	25.22 c	40.67 d	44.87 ef	52.53 e
N_3S_2	25.91 bc	42.90 c	46.53 d	54.97 cd
N_3S_3	27.87 a	45.33 a	51.10 a	58.77 a
$LSD_{(0.05)}$	0.86	1.29	0.98	1.37
F-test	**	**	**	**
CV (%)	2.14	1.88	1.29	1.53

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly, ** = Significant at 1% probability, N_0 = control, N_1 = 150, N_2 = 250 and N_3 = 350 kg N ha^{-1}, S_1 = 50 × 30, S_2 = 50 × 40 and S_3 = 50 × 50 cm

3.4. Number and weight of loose leaves plant^{-1} at harvest

The number and weight of loose leaves plant^{-1} at harvest showed significant variations due to nitrogen (Table 4). The maximum number (19.38) and the highest weight of loose leaves (862.20 g) plant^{-1} were recorded from plants receiving 350 kg N ha^{-1} but the minimum was in 250 kg N ha^{-1} (Table 4). The higher doses of nitrogen increased the number of loose leaves plant^{-1} that ultimately increased the weight of loose leaves. This result is in agreement with the findings of Pramanik (2007). The plant spacing also affected the number of loose leaves plant^{-1} significantly. The maximum number (19.22) and weight of loose leaves (869.40 g) plant^{-1} were in the widest spacing while the minimum was in the closest one (Table 4). The number and weight of loose leaves $plant^{-1}$ increased with the increase in spacing. Similar findings were also reported by Pramanik (2007). The number and weight of loose leaves $plant^{-1}$ were also influenced significantly by their combination and it was higher in N_3S_3 while the minimum was in N_1S_1 (Table 4).

3.5. Diameter and thickness of the head

The diameter and thickness of heads were influenced significantly due to nitrogen. The maximum diameter (19.51 cm) and thickness (12.58 cm) of head were measured for 350 kg N ha^{-1} while the lowest was for control (Table 4).

Table 4. Effect of nitrogen and spacing on the number and weight of loose leaves of cabbage, and diameter and thickness of heads at harvest

Treatments	Number of loose leaves $plant^{-1}$	Weight of loose leaves $plant^{-1}$ (g)	Diameter of the head (cm)	Thickness of the head (cm)
Nitrogen				
N_0	15.38 c	679.20 c	15.03 d	10.02 c
N_1	14.16 d	647.80 c	15.84 c	11.97 b
N_2	17.68 b	783.30 b	17.82 b	12.17 ab
N_3	19.38 a	862.20 a	19.51 a	12.58 a
$LSD_{(0.05)}$	0.93	35.26	0.49	0.47
F-test	**	**	**	**
Spacing				
S_1	13.98 c	617.50 c	15.63 c	11.14 c
S_2	16.74 b	742.40 b	16.31 b	11.57 b
S_3	19.22 a	869.40 a	19.22 a	12.34 a
$LSD_{(0.05)}$	0.81	30.53	0.42	0.41
F-test	**	**	**	**
Nitrogen x Spacing				
N_0S_1	15.27 de	674.2 de	14.33 j	9.87 f
N_0S_2	15.20 de	671.20 de	14.43 j	9.93 f
N_0S_3	15.67 d	692.10 de	16.33 fg	10.25f
N_1S_1	13.32 f	588.40 f	14.77 ij	11.33 e
N_1S_2	14.44 def	637.30 ef	15.43 hi	12.14 cde
N_1S_3	14.72 def	717.60 d	17.33 de	12.42 bc
N_2S_1	13.55 f	598.30 f	15.80 gh	11.58 de
N_2S_2	18.13 c	807.60 c	16.73 ef	11.87 cde
N_2S_3	21.35 b	944.10 b	20.93 b	13.05 ab
N_3S_1	13.80 ef	609.20 f	17.60 d	11.79 cde
N_3S_2	19.20 c	853.50 c	18.63 c	12.32 bcd
N_3S_3	25.14 a	1124.00 a	22.28 a	13.63 a
$LSD_{(0.05)}$	1.62	61.07	0.84	0.82
F-test	**	**	**	Ns
CV%	5.73	4.85	2.93	4.15

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly, ns = non significant, ** = Significant at 1% probability, N_0 = control, N_1 = 150, N_2 = 250 and N_3 = 350 kg N ha^{-1}, $S_1 = 50 \times 30$, $S_2 = 50 \times 40$ and $S_3 = 50 \times 50$ cm

The higher doses of nitrogen probably ensured vigorous growth of plant and consequently resulted in the highest diameter and thickness of heads but those gave lesser compactness of heads. Pramanik (2007) also reported similar result and opined that the diameter and thickness of head increased with the increasing level of nitrogen that favored the growth of plants. The diameter and thickness of heads varied significantly due to plant spacing too. The highest diameter and thickness of head were recorded from S_3 and the lowest was from S_1. The diameter and thickness of heads were increased with the increase in spacing (Table 4). That occurred due to availability of sufficient amount of light and nutrients to plants. Kumar and Rawat (2002), Mahesh-Kumar (2002) and Pramanik (2007) also reported similar results. The highest diameter and thickness of a head (22.28) was in N_3S_3 while the lowest (14.33 cm) was in N_0S_1 (Table 4). This result is also agreed with that of Kumar and Rawat (2002) who claimed that nitrogen and spacing influenced the diameter and thickness of heads.

3.6. Fresh weight of the head plant^{-1}

The fresh weight (excluding the weight of loose leaves) of the head plant^{-1} showed significant difference due to nitrogen. The highest fresh weight of the head plant^{-1} (1.80) was in N_3 and it was statistically similar to that of N_2 while the lowest (0.82 kg) was in control (Table 5). The optimum dose of nitrogen may ensure proper growth of plant resulting the highest fresh weight of head plant^{-1} too. The present result is also at per to those of Mahesh-Kumar (2002) and Pramanik (2007) where they argued that the higher yield in cabbage was associated with increased nitrogen rate and the higher nitrogen levels favored the growth of plants with larger leaf area. The highest fresh weight of the head plant^{-1} (1.65) was also noted in the widest spacing but the lowest (1.32 kg) was in the closest spacing (Table 5). The fresh weight of the head plant^{-1} increased with the increase in spacing due to more availability of light and nutrients. The similar result was also reported by Mannan *et al*. (2001), Mahesh-Kumar (2002), Kumar and Rawat (2002) and Pramanik (2007). The highest fresh weight of the head plant^{-1} (2.17) was in N_2S_3, while the lowest (0.78 kg) was in N_0S_1 (Table 5). Kumar and Rawat (2002) and Aquino *et al.* (2005) also claimed that nitrogen and spacing influenced the yield and quality of cabbage.

3.7. Dry matter content of the head plant^{-1}

The highest dry matter content of the head plant^{-1} was in N_3 coupled with the widest spacings while the lowest was in N_0 with the closest spacing. Significant variation was also found in their combination in terms of the dry matter content of the head plant^{-1} (Table 5).

3.8. Gross yield of cabbage hectare^{-1}

The gross yields of cabbage exhibited statistically significant differences due to different levels of applied nitrogen. The maximum gross yield (106.30 t ha^{-1}) was recorded in N_3 and it was statistically similar (102.80 t ha^{-1}) to N_2 while the lowest (60.01 t ha^{-1}) was in N_0 (Table 5). Parmar *et al.* (1999) reported that the higher yields in cabbage were associated with the increased rates of applied nitrogen. The maximum gross yield (100.80 t ha^{-1}) was recorded in the widest spacings while the lowest (77.40 t ha^{-1}) from the closest spacing. This result revealed that the gross yield increased with the increases in spacing (Table 5). That was due to the availability of sufficient amount of light and nutrients that led to the optimum vegetative growth and gave the maximum yield. This result is also in agreement with the findings of Mannan *et al.* (2001), Amreesh (2002), Mahesh-Kumar (2002), Fujiwara (2003) and Pramanik (2007). Significant variations were further recorded due to the combined effect of nitrogen and spacing in terms of gross yield. The maximum gross yield (126.30 t ha^{-1}) was in N_3S_3 while the lowest (58.17 t ha^{-1}) was in N_0S_1 (Table 5). The present result is at per to that of Aquino *et al*. (2005).

3.9. Marketable yield of cabbage head hectare^{-1}

The marketable yield of cabbage head showed significant differences due to applied nitrogen. The maximum marketable yield (72.00 t ha^{-1})

was recorded in N_3, but it was statistically similar (71.60 t ha^{-1}) to N_2 (Table 5). The optimum dose of nitrogen ensured proper growth of plants, lesser number of loose leaves and consequently the highest fresh weight of the head $plant^{-1}$. The present result agrees with that of Pramanik (2007) where he noted that, the higher yields in cabbage was associated with increased nitrogen rate. The higher nitrogen levels favored the growth of plants with larger leaf area and it was more effectively utilized in head formation, head diameter and number of marketable heads too. The marketable yield of cabbage also varied significantly due to spacing.

Table 5. Effect of nitrogen on the fresh weight of head, dry matter content head, gross and marketable yield of cabbage

Treatments	Fresh weight of the head $plant^{-1}$ (kg)	Dry matter content of the head (%)	Gross yield (t ha^{-1})	Marketable yield (t ha^{-1})
Nitrogen				
N_0	0.82 c	4.98 c	60.01 c	32.84 c
N_1	1.46 b	6.10 b	84.40 b	58.49 b
N_2	1.80 a	7.10 a	102.80 a	72.00 a
N_3	1.79 a	7.37 a	106.30 a	71.60 a
$LSD_{(0.05)}$	0.11	0.38	4.13	4.21
Spacing				
S_1	1.32 c	5.80 b	77.40 c	52.70 c
S_2	1.43 b	5.90b	86.90 b	57.20 b
S_3	1.65 a	7.46 a	100.80 a	66.07 a
$LSD_{(0.05)}$	0.09	0.33	3.58	3.65
Nitrogen x Spacing				
N_0S_1	0.78 d	4.73 c	58.17 e	31.20 d
N_0S_2	0.80 d	4.87 c	58.98 e	32.13 d
N_0S_3	0.88 d	5.33 c	62.88 e	35.20 d
N_1S_1	1.41 c	6.27 b	79.94 d	56.40 c
N_1S_2	1.56 bc	5.31 c	87.76 c	62.27 bc
N_1S_3	1.42 c	6.73 b	85.50 cd	56.80 c
N_2S_1	1.51 bc	6.17 b	84.47 cd	60.53 bc
N_2S_2	1.67 b	6.43 b	99.24 b	66.93 b
N_2S_3	2.17 a	8.70 a	124.70 a	86.93 a
N_3S_1	1.57 bc	6.30 b	87.04 cd	62.67 bc
N_3S_2	1.69 b	6.73b	101.60 b	67.47 b
N_3S_3	2.03 a	9.07 a	126.28 a	81.33 a
LSD $_{(0.05)}$	0.18	0.67	7.15	7.29
F-test	**	**	**	**
CV (%)	7.34	6.16	4.78	7.34

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly, ** = Significant at 1% probability, N_0 = Control, N_1 = 150, N_2 = 250 and N_3 = 350 kg Nha^{-1}, S_1 = 50 × 30, S_2 = 50 × 40 and S_3 = 50 × 50 cm

The maximum marketable yield (66.07 t ha^{-1}) was recorded for the widest spacing and the lowest (52.70 t ha^{-1}) for the closest spacing. This result revealed that the gross yield was increased with the increasing of spacing (Table 5), due to the availability of sufficient amount of light and nutrients that lead to optimum vegetative growth and gave the maximum yield. The trends of the present results agrees with that of Mannan *et al.* (2001), Amreesh (2002), Kumar and Rawat (2002), Mahesh-Kumar (2002), Fujiwara (2003), Esmail, (2004) and Pramanik (2007). Significant variations were recorded due to the combined effect of nitrogen and spacing in respect of the marketable yield. The maximum marketable yield (86.93 t ha^{-1}) was observed from N_2S_3, but it was statistically similar to N_3S_3 (81.33 t ha^{-1}) while the lowest (31.20 t ha^{-1}) was in N_0S_1 (Table 5). The results also agreed with those of Kumar and Rawat (2002) and Aquino *et al.* (2005).

3.10. Economic analyses

The cultivation cost increased with the increased doses of fertilizer (Table 6). The maximum benefit-cost ratio of 3.04 was recorded from the treatment combination of 250 kg N ha^{-1} (N_2) with wider spacing (N_2S_3) 50 × 50 cm.

Table 6. Economic analyses of cabbage production as influenced by nitrogen and plant spacing

Treatment combinations	Marketable yield (t ha^{-1})	Total cost of production (Tk. ha^{-1})[a]	Gross return (Tk. ha^{-1})[b]	Net profit (Tk. ha^{-1})	Benefit cost ratio
N_0S_1	31.20	125032.50	156000	30967.50	1.25
N_0S_2	32.13	125032.50	160650	35617.50	1.28
N_0S_3	35.20	125032.50	176000	50967.50	1.41
N_1S_1	56.40	135903.75	282000	146096.30	2.07
N_1S_2	62.27	135903.75	311350	175446.30	2.29
N_1S_3	56.80	135903.75	284000	148096.30	2.09
N_2S_1	60.53	143162.40	302650	159487.60	2.11
N_2S_2	66.93	143162.40	334650	191487.60	2.34
N_2S_3	86.93	143162.40	434650	291487.60	3.04
N_3S_1	62.67	150454.50	313350	162895.50	2.08
N_3S_2	67.47	150454.50	337350	186895.50	2.24
N_3S_3	81.20	150454.50	406000	255545.50	2.69

[a] Calculated on the basis of February 2013 market price
[b] Considering Tk. 5 kg^{-1} of marketable head of cabbage at harvest

4. Conclusions

The yield of cabbage head was influenced greatly by both applied nitrogen and spacing. Higher doses of nitrogen increased the number of loose leaves plant^{-1} that increased the gross yield but ultimately decreased the marketable yield of cabbage head. The head yield increased due to optimum levels of nitrogen and spacing too. The cultivation cost increased with the increased doses of nitrogen up to N_2. The maximum benefit-cost ratio of 3.04 was noted with 250 kg N ha^{-1} with 50 × 50 cm spacing and therefore, it was more suitable for cabbage production.

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