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Growth and yield performance of cabbage (*Brassica oleracea* var. *capitata* L.) as influenced by doses of nitrogen and zinc fertilizers

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ABSTRACT

The present study was conducted at the Horticulture Farm of the Department of Horticulture, Bangladesh Agricultural University during the period from October 2022 to February 2023 to assess the effects of different doses of nitrogen (N) and zinc (Zn) on growth and yield of cabbage. The two-factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The first factor was nitrogen having four doses of N, such as N_0 = 0 kg ha^{-1}, N_1 = 100 kg ha^{-1}, N_2 = 150 kg ha^{-1} and N_3 = 200 kg ha^{-1}, and four doses of Zn, namely Zn_0 = 0 kg ha^{-1}, Zn_1= 1.5 kg ha^{-1}, Zn_2 = 2.0 kg ha^{-1}, Z_3 = 2.5 kg ha^{-1}. Significant variations were noted due to the application of different doses of N and Zn fertilizers in respect of all the growth and yield traits studied. Application of N at 200 kg ha^{-1} contributed the best outcomes on plant height (32.72 cm), number of leaves per plant (47.86), gross yield per hectare (69.99 t), marketable yield per hectare (45.98 t) and the lowest yield per hectare (64.52 t), the lowest marketable yield per hectare (38.37 t) were obtained from control treatment. The highest level of zinc (2.5 kg ha^{-1}) produced the best results on plant height (32.30 cm), number of leaves (48.26) per plant, gross yield per hectare (78.02 t), marketable yield per hectare (61.62 t) and the lowest gross yield per hectare (59.17 t), lowest marketable yield per hectare (29.40 t) produced from control treatment. The maximum doses of nitrogen and zinc (200 kg ha^{-1} and 2.5 kg ha^{-1}), respectively showed the best performance on plant height (33.32 cm), number of leaves (49.53) per plant, gross yield per hectare (81.15 t), marketable yield per hectare (65.78 t) and the lowest gross yield per hectare (55.41 t) and marketable yield per hectare (27.28 t) were obtained from the control treatment. The results of this investigation revealed that application of N and Zn enhanced the affects the growth and yield of cabbage. However, further investigation may be carried out with higher doses of N and Zn fertilizers.

Keywords: Macro- and micro nutrients, balanced fertilization, production, cabbage

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1 Introduction

Cabbage (*Brassica oleracea* var. *capitata* L.) is one of most delicious and nutritious green leafy vegetables in Bangladesh. Locally it is known by the name 'Bhadha Kopi'. It is an important member of Cole crops under the family Brassicaceae originated from

Western Europe and Northern shores of Mediterranean Sea (Chauhan, 1986). Cabbage is an excellent source of vitamin A, C and K. An edible portion of 100 g cabbage contains 1.8 g protein, 0.1g fat, 4.6 g carbohydrate, 0.6 g mineral, 29 mg Ca, 0.8 mg Fe and 14.1 mg Na (FAOSTAT, 2000). Besides it's nutritive value, it also has some medicinal value as it prevents constipation, prevent cancerous cell growth, increases appetite, speeds up digestion and is very useful for diabetic patient (Kirsh et al., 2007).

Cabbage is an herbaceous biennial plant that produces compact heads which is the main edible part of the plant formed by overlapping fleshy leaves. It is one of the popular vegetables grown during the winter season of Bangladesh. Meherpur, Kushtia, Jashore and Bogura districts are the leading production area. Among all the vegetables grown in Bangladesh, cabbage ranks second in respect of production and area (Ali and Kashem, 2018). It is cultivated in an area of 22.35 thousand hectares with a total production of 380 thousand tons in 2019-2020 (BBS, 2021). In 2021-2022, cabbage production climbed to 395 thousand tons in the country (BBS, 2021). The average yield of cabbage is very low in Bangladesh compared to other developed countries viz., South Korea (61.17 t ha^{-1}), Germany (54.81 t ha^{-1}.), Japan (40.32 t ha^{-1}) and India (19.10t ha^{-1}) while ours remain on 9.39 t ha^{-1} (Akhtar, 2015). The reasons for such poor growth and yield of cabbage are lack of using modern technology, judicious application of fertilizers and proper management practices (Olaniyi and Ojetayo, 2011; Hossain et al., 2023).

Cabbage is well known to be an exhaustive crop and has the capacity to absorb higher amount of nutrient from soil (Naher et al., 2015). The supply of proper nutrient must be ensured during its cultivation. Nitrogen plays a vital role on the vegetative growth of the plant. It has been reported that nitrogen deficit plants show slower growth and produce small and yellow leaves (Akand et al., 2015). If a plant is supplied optimum amount of nitrogen, there is tendency to increase leaf cell number and cell size with an overall increase in leaf production (Morton and Watson, 1948). Nitrogen plays an important role in the building up of protoplasm and protein which induce cell division and initiate meristematic activities when applied in optimum quantity (Akand et al., 2015; Lakra et al., 2017). Low nitrogen availability causes a decrease in cell size especially cell division (Prasad et al., 2009).

Zinc (Zn) deficiency is widespread nutrient disorder in in Asia, especially in Bangladesh (Quijano-Guerta et al., 2002; Islam et al., 2021). Zinc is a micronutrient recognized as essential for plants and has assumed greater significance due to wide occurrence in different agro climatic regions of the country, spectacular response of field and fruit crops to its application. Zinc is essential component of many enzymes such as carbonic anhydrase, alcohol dehydrogenase, superoxide dismutase and RNA polymerase etc. (Muralisankar et al., 2014). Among the micronutrients zinc play a pivotal role in plant growth and development. Zinc deficiency affects stem elongation activities and protein synthesis. Due to deficiency of zinc, plant shows several abnormalities and malformations causing a reduced new vegetative growth and development of smaller and narrow leaves (Broadley et al., 2012).

In Bangladesh, cabbage is grown in winter season, which comprises the months from Mid-October to Mid-March. The maximum yield of cabbage is associated with the optimum doses of nitrogen and zinc (Atanasova, 2008; Sharma et al., 2021). It is evident that different sources of nutrients are important factor in crop production. Among the major macro and micro nutrients, nitrogen and zinc, respectively are used by the plants for better physio-morphological and biological development. Nitrogen increases the yield and number of marketable heads and application of zinc improves the higher yield (Yebirzaf, 2017; Singh and Singh, 2017). In Bangladesh, average yield of cabbage is lower than that of other developed countries due to due to the improper use of fertilizers and the neglect of micronutrients (Zihad et al., 2019). Therefore, it is necessary to improve the yield of cabbage through judicious application of macro and micro nutrients particularly nitrogen and zinc fertilizers. Therefore, the present study was conducted to investigate the effects of different doses of nitrogen and zinc fertilizers on growth and yield performance of cabbage.

2 Materials and Methods

2.1 Study location

The experiment was conducted at the Horticultural Farm of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh, during the period from October 2022 to February 2023 with a view to find out the optimum doses of nitrogen (N) and zinc (Zn) fertilizers for enhancing growth and yield of cabbage. The experiment was carried out on a medium high land Old Brahmaputra Flood Plain Alluvial Tract (UNDP, 1988) of AEZ-9. The texture of the soil was silty loam with pH 6.5. The climate of the experimental area was subtropical in nature, which was characterized by high temperature, heavy rainfall, high humidity and relatively long day during the months of April to September and low rainfall associated with moderately low temperature, low humidity and short day during the rest of the year.

2.2 Collection of plant materials

The cultivar of cabbage used in the experiment was Atlas-70, which was developed by TAKII Co. Ltd. Kyoto, Japan. The seeds of the variety were F1-Hybrid and collected from Moushumi Beej Bitan, Rambabu Road, Mymensingh.

2.3 Experimental design and layout

The experiment contained four doses of nitrogen viz. N_0 = 0 (no nitrogen) control, N_1 = 100 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 200 kg N ha^{-1} and four different doses of zinc viz. Zn_0 = 0 (no zinc) control, Zn_1 = 1.5 kg Zn ha^{-1}, Zn_2 = 2.0 kg Zn ha^{-1}, Z_3 = 2.5 kg Zn ha^{-1}. The experiment was laid out in randomized complete block design with three replications. There were 16 treatments including a control which were assigned randomly to the plot of 2.4 m × 2 m in size. The experiment area was divided into three blocks consisting of sixteen-unit plots of each. Therefore, the total number of plots was 48. The block to block and plot to plot distances were 1m and 0.5m, respectively. Plant spacing was 60 cm × 50 cm and 16 plants per unit were accommodated. The total area of the experiment plots was 408 m^2.

2.4 Methods of cabbage cultivation

The seedlings were raised with intensive care in 3 m × 1 m seed bed. The soil of the seedbed was well ploughed with a spade in order to obtain good tilth. The unwanted plants and other materials were removed from the field. The seeds were sown in seedbed on October 25, 2022. Besides N and Zn, the cabbage was fertilized with cowdung, TSP, MoP, and gypsum following Fertilizer Recommendation Guide (BARC, 2018). Urea and zinc sulphate were used as the sources of N and Zn, respectively. Entire amount of cowdung, TSP, zinc sulphate and 1/3rd urea and MoP were applied during final land preparation. Resot of urea and and MoP were applied i three equal installments at 15, 30, 45 and 60 DAT.

Twenty seven-day-old seedlings were transplanted on 15 November 2023. Four times weeding were done at 15, 30, 45 and 60 DAT. The cabbage also irrigated at seven days interval using watering cane. and irrigation when needed. The damaged or dead seedlings were replaced with healthy ones from the border plants. Cutworm attack and foot rot disease is a serious problem for cabbage cultivation after transplanting of seedlings. Melathion 57EC @ 2 mL L^{-1} and Ridomil MZ 68 @ 2 g L^{-1} water sprayed to mitigate the insect attack or disease infestation. The plants were also sprayed with Dimethoate 30% EC at interval of 20 days from the age of 45 days and up to a week before maturity. The crop was harvested on February, 2023, when the heads become well compact with the maturity. The maturity was checked by pressing the thumb. The compact or mature head showed comparatively hard feeling. Proper care was taken during harvesting period to prevent damages of leaves.

2.5 Data collection

Four plants were randomly selected from the middle rows of unit plot for avoiding border effect, except yield cards. The data of plant height (cm), plant spread (cm), number of leaves per plant, length of largest leaf (cm), breadth of largest leaf (cm) was collected at 15, 30, 45, and 60 days after transplanting (DAT). Meanwhile, the yield attributing characters such as length of the stem (cm), fresh weight of root (cm), diameter of the cabbage head (cm), % dry matter content, thickness of the cabbage (cm), gross yield (t ha^{-1}), weight of marketable head (kg) and marketable yield (t ha^{-1}) were noted at full maturity.

2.6 Statistical analysis

For statistical evaluation of data on various parameters, Statistix 10 software was used. All the collected data were analyzed statistically following the ANOVA technique and the significance of difference between pairs of means was evaluated by LSD test at 1% and 5% level of probability (Gomez and Gomez, 1984).

3 Results and Discussion

3.1 Plant height

Plant height is an important growth contributing characters of cabbage plant. Plant height was recorded at 15, 30, 45 and 60 DAT. The height of plant increased progressively from 15 DAT to 60 DAT. The application of different levels of nitrogen markedly influenced the height of plant. The highest plant height (32.72 cm) was recorded when nitrogen applied @200 kg ha^{-1} at 60 DAT and the lowest (30.79 cm) was recorded from the control treatments (0 kg ha^{-1}) at 60 DAT (Fig. 1a). A study conducted by Prasad et al. (2009) described that different dose of nitrogen has high impact on foliage growth and height development also responsible for giving plants their green coloring by helping with chlorophyll production. Similar results were obtained by Haque et al. (2006), who mentioned that plant height was significantly increased as N application rate increased. The result of zinc treatment showed highly significant effect on the height of cabbage plants at 15, 30, 45 and 60 DAT. The maximum height of the plant (32.30 cm) was recorded from Z_3 (2.5 kg ha^{-1}) treatment at 60 DAT while the lowest height of the plant (31.18 cm) was recorded from the control treatment (0 kg ha^{-1}) at 60 DAT (Fig. 1b). Foliar application of zinc and boron on cabbage plant

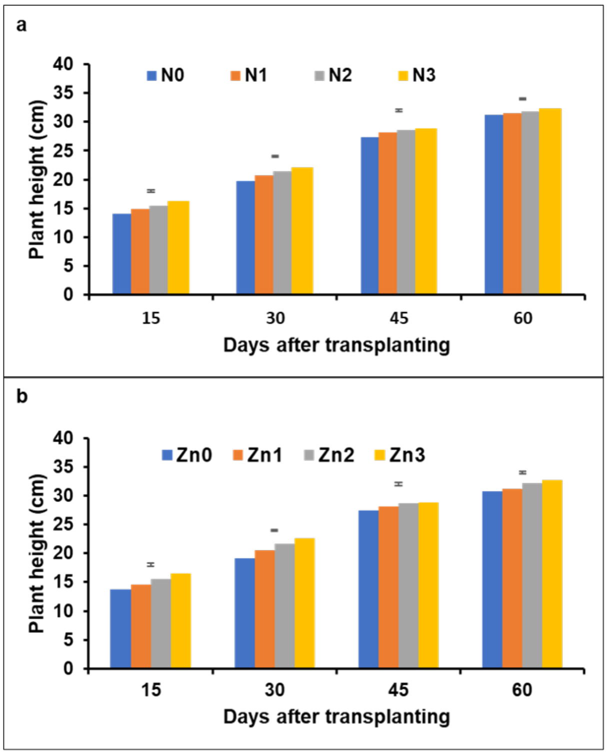

Figure 1. Main effect of different doses of N (a) and Zn (b) on plant height at different DAT. The vertical bars represent LSD at 1% level of probability. N_0, N_1, N_2 and N_3 indicate doses of nitrogen (N) at 0, 100, 150 and 200 kg ha^{-1}, respectively; Zn_0, Zn_1, Zn_2 and Z_3 indicate doses of zinc (Zn) at 0, 1.5, 2.0 and 2.5 kg ha^{-1}, respectively

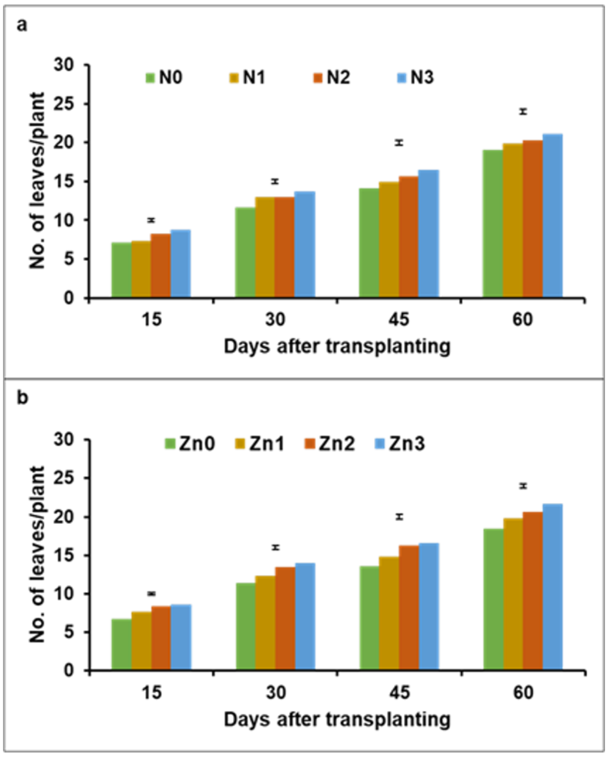

Figure 2. Main effect of different doses of N (a) and Zn (b) on number of leaves at different DAT. The vertical bars represent LSD at 1% level of probability. N_0, N_1, N_2 and N_3 indicate doses of nitrogen (N) at 0, 100, 150 and 200 kg ha^{-1}, respectively; Zn_0, Zn_1, Zn_2 and Z_3 indicate doses of zinc (Zn) at 0, 1.5, 2.0 and 2.5 kg ha^{-1}, respectively

shows impactful result on plant height of cabbage. A maximum plant height (36.33 cm) was recorded from the experiment conducted by Taheri et al. (2020). The interaction effect of nitrogen and zinc influenced the height of the cabbage? greatly. The highest plant height (33.32 cm) was recorded with the application of 200 kg ha^{-1} of nitrogen and 2.5 kg ha^{-1} of zinc at 60 DAT while the lowest height of the plant (30.18 cm) was with no application of nitrogen and zinc (Table 1).

3.2 Number of leaves per plant

Good foliage represents higher growth, development and higher yield of crop which can be obtained by supplying proper nutrition through fertilizers. On that contrary, nitrogenous and zinc fertilizers can be a great source for influencing vegetative growth. The maximum number of leaves per plant (21.65) was acquired from N_3 (200 kg ha^{-1}) and the lowest of leaves per plant (18.41) was obtained from the plant receiving N_0 (without nitrogen) (Fig. 2a). On the other hand, effect of zinc alone on leaves per plant was highly significant at different days after transplanting (DAT). The maximum number of leaves per plant (21.15) was recorded in Z_3 (2.5 kg ha^{-1}) treatment while the minimum (19.09) was observed under control in Zn_0 (without zinc) (Fig. 2b). Application of nitrogen and zinc altogether showed statistically significant interaction effect on the number of leaves per plant. The highest number of leaves per plant (22.33) was noted by the treatment combination of N_3Z_3 followed by N_3Zn_2 (22.13) and the lowest (17.36) was noted by the treatment N_0Zn_0 (Table 1). According to the study of Pongrac et al. (2018) the number of leaves increases to the higher doses of zinc supply. These results also coincide with the results of Ali et al. (2019), who reported that application of different doses of nitrogen viz. 30 kg, 45 kg and 60 kg on cole crops like cauliflower, cabbage provide results with increased number of leaves.

Table 1. Interaction effects of different doses of N and Zn on plant height and number of leaves of cabbage at different days after transplanting (DAT)

Treatment	Plant height (cm) at different DAT				Number of leaves (cm) at different DAT			
	15	30	45	60	15	30	45	60
N_0Zn_0	12.51	18.28	26.32	30.18	5.76	10.34	12.8	17.36
N_0Zn_1	13.54	18.67	27.40	30.56	6.32	11.53	13.61	18.27
N_0Zn_2	13.91	19.22	27.84	31.01	7.23	11.45	13.45	18.77
N_0Zn_3	15.21	20.31	28.12	31.39	7.73	12.26	14.46	19.25
N_1Zn_0	13.32	19.42	27.09	30.80	6.62	11.34	13.50	18.84
N_1Zn_1	14.12	20.35	28.15	31.09	6.89	12.51	14.66	19.40
N_1Zn_2	14.93	20.83	28.50	31.15	8.33	12.25	15.44	19.68
N_1Zn_3	15.85	21.22	28.94	32.10	8.75	13.37	15.78	21.18
N_2Zn_0	14.50	20.23	27.69	31.47	7.57	12.31	15.67	19.56
N_2Zn_1	15.33	21.44	28.55	32.23	7.88	13.54	15.68	20.40
N_2Zn_2	15.86	22.12	29.04	32.16	8.77	13.95	16.44	20.63
N_2Zn_3	16.43	22.72	29.25	32.42	9.24	14.29	17.35	21.85
N_3Zn_0	15.65	21.17	28.25	32.27	8.34	12.65	14.65	20.62
N_3Zn_1	16.25	22.24	28.78	32.51	8.27	14.16	15.94	21.51
N_3Zn_2	17.02	23.28	28.96	32.78	8.73	14.27	17.37	22.13
N_3Zn_3	17.31	23.82	29.32	33.32	9.18	15.04	18.40	22.33
$LSD_{0.01}$	0.46	0.36	0.31	0.22	0.33	0.56	0.62	0.55
Sig. level	**	**	**	**	**	**	**	**

** indicates significant at $p \leq 0.01$; N_0, N_1, N_2, and N_3 indicate doses of nitrogen (N) at 0, 100, 150 and 200 kg ha^{-1}, respectively; Zn_0, Zn_1, Zn_2, and Zn_3 indicate doses of zinc (Zn) at 0, 1.5, 2.0 and 2.5 kg ha^{-1}, respectively

3.3 Plant spread and breadth of the largest leaf

The plant spread increased gradually and attained maximum up to 60 DAT. At 60 DAT, the largest plant spread (47.86 cm) was recorded from the treatment of N_3 (200 kg ha^{-1}) whereas the smallest plant spread (45.64 cm) was obtained under control treatment (without treatment) (Table 2). Effect of zinc alone on leaf spread of plant was highly significant at different DAT The maximum plant spread (45.24 cm) was obtained from the treatment Z_3 (2.5 kg ha^{-1}) whereas the minimum plant spread (43.64 cm) was measured under control treatment Zn_0. Interaction effect of nitrogen and zinc also have significant difference on plant spread, as the highest value was observed (49.53 cm) was recorded from the application of 200 kg ha^{-1} nitrogen and 2.5 kg ha^{-1} zinc at 60 DAT and the minimum (45.53 cm) was obtained without the application of nitrogen and zinc (Table 2). Similarly, the result found in N_3 (33.17 cm) and Z_3 (33.07 cm) was higher at the longest day. On interaction treatment N_3Z_3 the largest leaf breadth (35.24 cm) was measured at 60 DAT preceded by N_3Zn_2 (34.53 cm) and N_2Z_3 (34.36 cm) (Table 2). Mahmoud et al. (2004) performed an experiment on cabbage using two dosages of nitrogen fertilizer (40 kg and 80 kg) and 12% zinc as a foliar spray, which boosted the plant's breadth and might result in bigger leaves.

3.4 Length of the cabbage stem

The application of nitrogen had significant effect on the length of the stem of cabbage. The stem length was found to be the highest (5.53 cm) in N_3 (200 kg ha^{-1}) treatment and the lowest stem length (4.70 cm) was observed in control (N_0 = 0 kg ha^{-1}) treatment (Table 3). Zinc had also significant effect on stem length. Length of the stem increased with the increasing doses of zinc. Z_3 (2.5 kg ha^{-1}) treatment produced the maximum length of the stem (5.37 cm) while minimum length of the stem (5.12 cm) was observed in Zn_0 (no zinc). The length of the stem among the treatment combination of nitrogen and zinc was found to be statistically significant. Length of the stem is highest (5.66 cm) at the treatment N_3Z_3 (200 kg ha^{-1} nitrogen and 2.5 kg ha^{-1} zinc) while the lowest was (4.54 cm) at the treatment combination of N_0Zn_0 (Table 3). The apparent elongation with increasing amount of nitrogenous fertilizer may be attributed to the increase stem elongation of cabbage is evident by Riad et al. (2009) and in this case increasing N fertilization increased plant elongation. Ahmed et al. (2023) tested a hypothesis using three different zinc applications on vegetative growth of cabbage in which development of phenotypic growth such as plant height, length of cabbage stem, thickness of cabbage head are to be found satisfactory.

Table 2. Main and interaction effects of different doses of N and Zn on plant spread and breadth of largest leaf of cabbage at different DAT

Treatment	Plant spread (cm) at different DAT				Breadth of the largest (cm) at different DAT			
	15	30	45	60	15	30	45	60
Nitrogen (N)								
N_0	20.53	26.27	35.09	45.64	7.59	11.87	16.66	23.91
N_1	21.77	26.76	35.88	46.14	8.36	13.54	18.26	26.5
N_2	23.18	27.62	36.95	47.7	9.89	14.46	21.44	27.46
N_3	25.19	29.2	38.06	47.86	10.38	14.76	21.87	28.1
$LSD_{0.01}$	0.17	0.27	0.24	0.37	0.22	0.25	0.29	0.18
Sig. level	**	**	**	**	**	**	**	**
Zinc (Zn)								
Zn_0	21.43	26.17	32.09	43.64	7.97	12.04	18.12	24.31
Zn_1	22.57	25.76	34.88	45.24	8.97	13.27	19.28	25.86
Zn_2	23.18	27.82	37.95	47.72	9.25	14.06	20	27.59
Zn_3	24.21	29.2	38.16	48.82	10.03	15.26	20.83	28.21
$LSD_{0.01}$	0.17	0.27	0.24	0.37	0.22	0.25	0.29	0.18
Sig. level	**	**	**	**	**	**	**	**
Interaction (N × Zn)								
N_0Zn_0	19.26	24.65	34.39	43.53	6.74	10.46	15.48	21.73
N_0Zn_1	20.09	25.49	33.84	45.23	7.56	12.26	17.19	23.58
N_0Zn_2	20.95	26.7	35.63	46.48	7.44	11.36	16.42	25.05
N_0Zn_3	21.83	28.23	36.48	47.3	8.6	13.41	17.56	25.28
N_1Zn_0	20.08	24.97	34.62	44.33	7.44	11.68	17.11	23.73
N_1Zn_1	21.53	26.02	35.36	45.37	8.66	13.01	18.45	24.76
N_1Zn_2	22.23	27.33	36.44	47.11	8.37	14.29	18.29	28.16
N_1Zn_3	23.22	28.72	37.09	47.73	8.97	15.17	19.17	28.36
N_2Zn_0	21.19	25.75	35.65	46.62	8.4	12.68	20.33	25.4
N_2Zn_1	22.67	27.11	36.47	47.29	9.55	13.79	21.04	26.52
N_2Zn_2	23.54	28.34	37.35	48.47	10.41	15.18	21.99	28.41
N_2Zn_3	25.32	29.3	38.34	48.4	11.19	16.19	22.42	29.49
N_3Zn_0	23.54	28.34	37.35	48.47	9.29	13.34	19.54	26.38
N_3Zn_1	24.49	28.36	37.86	47.04	10.1	14	20.44	27.57
N_3Zn_2	25.62	30.1	38.47	48.4	10.77	15.41	23.32	28.76
N_3Zn_3	27.44	31.49	39.51	49.53	11.36	16.29	24.18	29.71
$LSD_{0.01}$	0.33	0.54	0.47	0.74	0.44	0.5	0.58	0.36
Sig. level	**	**	**	**	**	**	**	**

** indicates significant at $p \leq 0.01$; N_0, N_1, N_2, and N_3 indicate doses of nitrogen (N) at 0, 100, 150 and 200 kg ha^{-1}, respectively; Zn_0, Zn_1, Zn_2, and Zn_3 indicate doses of zinc (Zn) at 0, 1.5, 2.0 and 2.5 kg ha^{-1}, respectively

3.5 Fresh weight of root per plant

A measurement of fresh root weight of the plants was conducted at 60 DAT. At 60 DAT, the highest fresh weight of root (16.71 g) was recorded in N_3 (200 kg ha^{-1}) treatment while the lowest fresh weight of root per plant (9.98 g) was recorded from control (N_0) treatment (Table 3). On Z_3 treatment the largest root (14.36 g) was observed followed by Zn_1 (14.52 g) while the lowest weight (11.93 g) was recorded from the control (Zn_0) treatment (Table 3). When compared to plants with sufficient zinc, plants with deficiencies had much lower zinc concentrations in their leaves and roots. In comparison to plants supplied with enough Zn, plants with insufficient supply had Zn contents in their leaves and roots that were 95% and 63% lower, respectively. Zn content in the roots and shoots was decreased by 86% and 36%, respectively, due to a Zn deficit (Hajiboland and Amirazad, 2010). The application of nitrogen and zinc together also had significant effect on fresh weight of root on cabbage. The fresh weight of root per plant was varied from 8.73 g to 17.38 g being the maximum in case of the treatment combination doses of nitrogen N_3 (200 kg ha^{-1}) and zinc (2.5 kg ha^{-1}) and minimum was in control treatment (Table 3). Among all macro

Table 3. Main effect and interaction effect of different doses of N and Zn on yield and yield attributing characters of cabbage

Treatment	LS (cm)	FWR (g)	DCH (cm)	DMC (%)	TCH (cm)
Nitrogen (N)					
N_0	4.7	9.98	16.29	5.85	10.89
N_1	5.26	11.65	17.18	5.96	11.19
N_2	5.5	15.58	18.88	6.35	12.09
N_3	5.53	16.71	17.41	6.84	11.79
$LSD_{0.01}$	0.05	0.2	0.12	0.15	0.15
Sig. level	**	**	**	**	**
Zinc (Zn)					
Zn_0	5.12	11.93	17.13	4.99	10.72
Zn_1	5.19	13.85	17.29	5.73	11.16
Zn_2	5.31	13.77	17.15	6.85	11.77
Zn_3	5.37	14.36	18.19	7.43	12.31
$LSD_{0.01}$	0.05	0.2	0.12	0.15	0.15
Sig. level	**	**	**	**	**
Interaction (N × Zn)					
N_0Zn_0	4.54	8.73	16.12	4.62	10.3
N_0Zn_1	4.61	9.98	16.28	5.09	10.53
N_0Zn_2	4.78	10.37	16.34	6.41	11.22
N_0Zn_3	4.88	10.83	16.4	7.28	11.5
N_1Zn_0	5.14	11.53	16.31	4.72	10.56
N_1Zn_1	5.26	11.46	17.43	5.43	10.84
N_1Zn_2	5.32	11.7	16.64	6.57	11.66
N_1Zn_3	5.33	11.91	18.36	7.12	11.69
N_2Zn_0	5.37	12.86	18.64	5.36	11.54
N_2Zn_1	5.45	15.63	18.82	5.67	11.11
N_2Zn_2	5.57	16.48	18.94	6.88	12.61
N_2Zn_3	5.61	17.33	19.11	7.49	13.1
N_3Zn_0	5.43	14.59	17.46	5.25	10.46
N_3Zn_1	5.45	18.33	16.64	6.75	12.15
N_3Zn_2	5.56	16.54	16.68	7.55	11.58
N_3Zn_3	5.66	17.38	18.87	7.8	12.95
$LSD_{0.01}$	0.1	0.41	0.25	0.31	0.29
Sig. level	**	**	**	**	**

LS: length of the stem, FWR: fresh weight of root, DCH: diameter of the cabbage head, DMC: % dry matter content, TCH: thickness of the cabbage head; ** indicates significant at $p \leq 0.01$; N_0, N_1, N_2, and N_3 indicate doses of nitrogen (N) at 0, 100, 150 and 200 kg ha^{-1}, respectively; Zn_0, Zn_1, Zn_2, and Zn_3 indicate doses of zinc (Zn) at 0, 1.5, 2.0 and 2.5 kg ha^{-1}, respectively

and micronutrients, nitrogen is the motor element in all major processes of plant development and yield production, which drives plant growth and is a required component of protein. It effectively stimulates vegetative growth of cabbage plant as well as larger stems, leaves and roots (Tehulie and Belete, 2021).

3.6 Diameter of cabbage head

The study revealed that nitrogen and zinc have positive role on head diameter of cabbage on different doses of nitrogen and zinc. The highest head diameter (17.41 cm) was found from nitrogen (N_3 = 200 kg ha^{-1}) treatment and the lowest diameter (16.29 cm) was observed in control (N_0) (Table 3). Khadir et al. (1989) studied the effect of nitrogen on the boom and yield of cabbage and said that the most important head weight, diameter and yield have been greater at the most charge of nitrogen (376 kg ha^{-1}). The maximum diameter of head under zinc treatment was found (18.19 cm) in (Z_3 = 2.5 kg ha^{-1}) and the minimum head diameter (17.13 cm) with control (Zn_0) treatment. A study monitored by Sarker and Kashem (2021) found that the widest diameter of cabbage

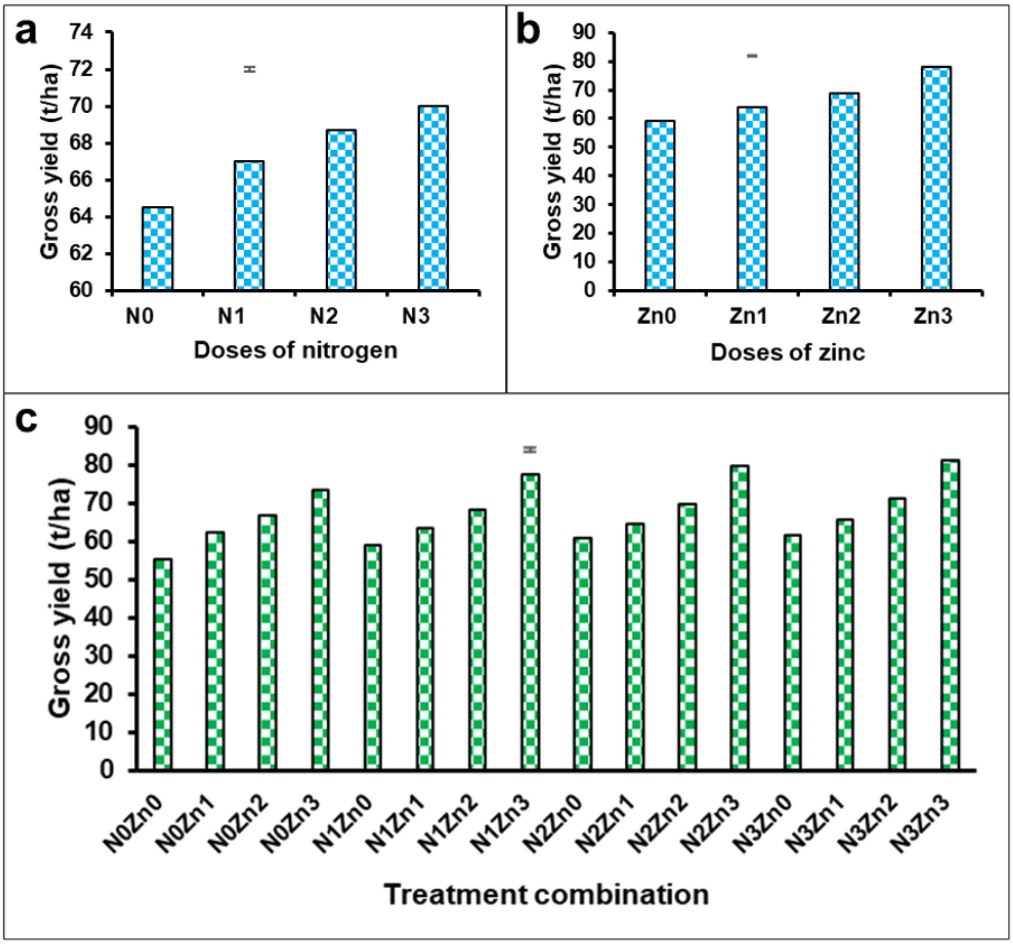

Figure 3. Main (a and b) and interaction (c) effects of different doses of N and Zn on gross yield per hectare of cabbage. The vertical bars represent LSD at 1% level of probability. N_0, N_1, N_2 and N_3 indicate doses of nitrogen (N) at 0, 100, 150 and 200 kg ha^{-1}, respectively; Zn_0, Zn_1, Zn_2 and Z_3 indicate doses of zinc (Zn) at 0, 1.5, 2.0 and 2.5 kg ha^{-1}, respectively

plant (24.70 cm) was achieved with the zinc treatment (1.5 kg ha^{-1}) while no application of zinc had adverse effect. The combination of nitrogen and zinc was found to be statistically significant. Result showed that treatment combination of N_3Z_3 gave the highest head diameter (18.87 cm). The lowest head diameter (16.12 cm) was obtained under control (N_0Zn_0) treatment combination (Table 3).

3.7 Dry matter content of head

Dry matter of head of cabbage was significantly influenced by the different levels of nitrogen and zinc. Single mean effects of different doses of nitrogen had been shown in the (Table 3) and it was observed that the dose of N_3 (200 kg ha^{-1}) produced a maximum percentage of dry matter content (6.84%) and the minimum percentage of dry matter (5.85%) was obtained from the control (N_0) treatment. The higher dry matter content was found under the treatment of Z_3 (2.5 kg ha^{-1}) (7.43%) and the lowest was found in control (4.99%). The combined effect of nitrogen and zinc showed significant variation where the highest value was found (7.80%) in N_3Z_3 (200 kg ha^{-1} nitrogen and 2.5 kg ha^{-1} zinc) while the lowest (4.62%) dry matter content was found in control (N_0Zn_0) (Table 3). The findings were also attained by McKeown et al. (2010) to reveal that the application of different doses of nitrogen significantly increased the dry matter content of cabbage head compared with untreated soil. Similarly applied Zn is reported to enhance the absorption of native as well as added major nutrients and thereby improved overall growth and development of plant and ultimately the yields. The highest dry matter (2.93 t ha^{-1}) yields were recorded with 7.5 kg Zn ha^{-1} which registered 36.5 and 31.4% higher head and dry matter production, respectively over control (Gaur and Singh, 2018).

3.8 Thickness of cabbage head

Thickness of cabbage head was influenced by the effect of nitrogen. The maximum thickness of head (11.79 cm) was found with the treatment of nitrogen

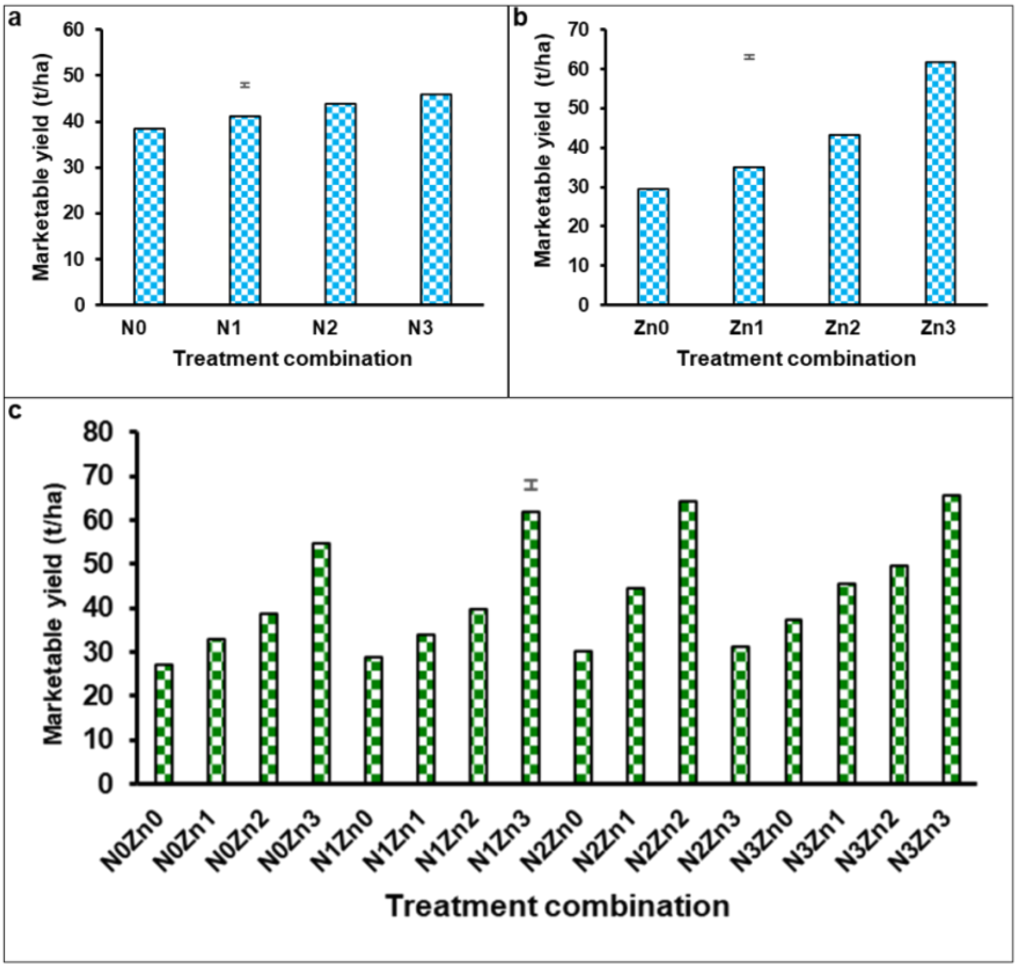

Figure 4. Main (a and b) and interaction (c) effects of different doses of N and Zn on marketable yield per hectare of cabbage. The vertical bars represent LSD at 1% level of probability. N_0, N_1, N_2 and N_3 indicate doses of nitrogen (N) at 0, 100, 150 and 200 kg ha^{-1}, respectively; Zn_0, Zn_1, Zn_2 and Z_3 indicate doses of zinc (Zn) at 0, 1.5, 2.0 and 2.5 kg ha^{-1}, respectively

(N_3 = 200 kg ha^{-1}) and minimum (10.89 cm) was observed in control (N_0 = 0 kg ha^{-1}) (Table 3). Similarly thickness of cabbage head significantly varied by zinc application. The maximum thickness of head (12.31 cm) was obtained with the treatment of zinc (Z_3 = 2.5 kg ha^{-1}) and the minimum thickness of head (10.72 cm) with the control (Zn_0) treatment. The combination of nitrogen and zinc showed much more result for (12.95 cm) N_3Z_3 treatment and the lowest was recorded (10.33 cm) for no application of nitrogen and zinc ((N_0Zn_0) (Table 3).

According to Haque et al. (2016), 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. Kumar and Rawat (2002) and Pramanik (2007) also reported similar results. By using six levels of zinc (0, 2.5, 5.0, 7.5, 10.0 and 15.0 kg ha^{-1}). Gaur and Singh (2018) concluded that highest doses of zinc produced thick cabbage head (36.06 t ha^{-1}).

3.9 Gross yield per hectare

In this present study a significant influence of different doses of nitrogen and zinc on gross yield per hectare was observed. Gross yield per hectare of cabbage were significantly influenced by the different doses of nitrogen treatment. The highest gross yield (69.99 t ha^{-1}) was obtained from highest nitrogen treatment (N_3 = 200 kg ha^{-1}) and the lowest gross yield (64.52 t ha^{-1}) was recorded with control (Fig. 3a). It is apparent that the maximum gross yield per hectare (78.02 t ha^{-1}) were recorded with the application of highest dose of zinc (2.5 kg ha^{-1}) and the lowest gross yield per plot (59.17 t ha^{-1}) were obtained from control (Zn_0) treatment of zinc (Fig. 3b). The application different doses zinc greatly influenced the gross yield of cabbage significantly where it varied from 51.71 to 63.36 t ha^{-1} in a experiment monitored by (Sarker and Kashem, 2021). In combined treatment, cabbage production per hectare differed significantly for different doses of nitrogen and zinc. The interaction treatment $N_3Zn\neg3$ produced the maximum gross yield (81.15 t ha^{-1}) whereas N_0Zn_0 produced the lowest gross yield (55.41 t ha^{-1}) preceded by N_1Z_3 (77.70 t ha^{-1}) (Fig. 3c). These findings are in coordinate with the reports of Dawit et al. (2020) who reported that cabbage yield amplify with increasing doses of nitrogen application (5.8 kg ha^{-1} and 33.15 kg ha^{-1} with 0 and one hundred twenty kg per hectare, respectively). Similarly, Pankaj (2006) mentioned that cabbage yield extended to 49.83 kg ha^{-1} with increasing rates of nitrogen up to 180 kg ha^{-1}.

3.10 Marketable yield per hectare

Weight of marketable head varied significantly among the treatment due to different sources of nutrients. Considering the weight of marketable head, it was evident that the weight of marketable head was found to be the highest (45.98 t ha^{-1}) in N_3(200 kg ha^{-1}) treatment and the lowest weight of marketable head (38.37 t ha^{-1}) was observed in control (Fig. 4a). Zinc was also significant on weight of marketable head of cabbage. The weight of marketable head was found to be the highest (61.62 t ha^{-1}) in Z_3 (2.5 kg ha^{-1}) treatment and lowest weight of marketable head (29.40 t ha^{-1}) was observed in control (Zn_0) treatment (Fig. 4b). The weight of marketable head among the treatment combination of nitrogen and zinc was found to be statistically significant. The weight of marketable head was the highest (65.78 t ha^{-1}) at the treatment combination of N_3Z_3 (200 kg ha^{-1} nitrogen and 2.5 kg ha^{-1} zinc) and the lowest (27.28 t ha^{-1}) was found in no application of nitrogen and zinc (N_0Zn_0) (Fig. 4c). Application of higher doses of nitrogen and zinc per hectare led to a considerable increase in total marketable output, when compared to half of this dose or lower ones. Which results in beneficial effect of high plant population on marketable yield of cabbage. This treatment boosts the head up to 2 kg while reducing the overall marketable yield by just around 1-1.5 kg (Kołota and Chohura, 2015; Sarker and Kashem, 2021).

4 Conclusion

The results indicated that 200 kg ha^{-1} nitrogen in combination with 2.5 kg ha^{-1} zinc application gave the highest yield but no application of nitrogen and zinc shows least yield compared to higher amount of nitrogen and zinc supply. In general, combination application of nitrogen and zinc enhances plant height, number of leaves per plant, plant spread, breadth of the largest leaf along with larger cabbage head, increases cabbage head with more compact cabbage head. Therefore, it can be concluded that 200 kg ha^{-1} of nitrogenous supply in combination with 2.5 kg ha^{-1} zinc fertilizer may be recommended for better growth, yield and quality of cabbage.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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