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Effect of GA_3 and NAA on Growth and Yield of Cabbage

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Abstract

Cabbage (Brassica oleracea var. capitata L.) is an important winter vegetable in Bangladesh; however, its yield remains considerably lower compared to that of major cabbage-producing countries. This study aimed to assess the effects of gibberellic acid (GA_3) and naphthalene acetic acid (NAA) on cabbage growth and yield, as well as to identify optimal application rates. The experiment was conducted using a randomized complete block design (RCBD) with eight treatments, including different concentrations of GA_3 (50, 75, and 100 ppm) and NAA (40, 60, 80, and 100 ppm), along with a control, at the Horticulture Farm of BARI, Gazipur. Findings revealed that GA_3 at 75 ppm significantly improved plant height (23.00 cm), total number of leaves (62.33), head diameter (22.60 cm), and yield (102.40 t ha^{-1}), achieving a 33.39% increase over the control. NAA at 60 ppm also showed notable, albeit slightly lower, improvements. Both growth regulators were effective in promoting earlier head formation and maturity. The results confirm that the exogenous application of GA_3 and NAA enhances vegetative growth and yield attributes in cabbage. Based on the findings, applying GA_3 at 75 ppm is recommended to maximize cabbage production under similar agro-ecological conditions. This study provides practical guidance for improving cabbage yield through the targeted use of plant growth regulators.

Keywords: *Plant growth regulators, Vegetative growth, Head yield, Foliar application*

Introduction

Cabbage (Brassica oleracea var. capitata L.), commonly referred to as “Badhacopy” in Bangladesh, belongs to the Brassicaceae family and is an important winter vegetable extensively grown across the country .It provides a wealth of essential nutrients like vitamins A, B, and C, along with minerals and beneficial bioactive compounds such as sinigrin glucoside, which enhance both its unique flavor and health-promoting properties. Additionally, cabbage is utilized in various culinary forms, including curries, salads, and pickles. The edible portion consists of tightly packed leaves forming the head, which is a vital economic trait. From a nutritional standpoint, every 100 grams of the edible green part of cabbage comprises about 92% water and supplies 24 kilocalories of energy, along with 1.5 grams of protein, 4.8 grams of carbohydrates, 40 milligrams of calcium, 0.6 milligrams of iron, 600 IU of carotene, 0.05 milligrams of riboflavin, 0.3 milligrams of niacin, and 60 milligrams of vitamin C. [1]. Cabbage also contains sulforaphane, a potent anti-carcinogenic compound, and increased consumption of plant-based foods such as cabbage has been linked to reduced risks of diabetes, obesity, heart disease, and overall mortality.

Although cabbage is an important crop in Bangladesh, its average yield is relatively low at 16.06 tons per hectare, falling well behind countries like Japan (40.03 t/ha), South Korea (59.07 t/ha), and even neighboring India (17.88 t/ha). [2]. This yield gap can be attributed primarily to suboptimal management practices and limited adoption of yield-enhancing technologies. Utilizing plant growth regulators (PGRs) is one promising approach to boosting cabbage production, as they significantly influence plant growth, development, and yield improvement. Plant growth regulators (PGRs) are organic substances that can alter various physiological functions in plants, even when applied in minimal amounts. Auxins like naphthalene acetic acid (NAA) mainly promote cell elongation, whereas gibberellins (GA_3) encourage both cell division and elongation. [3]. External application of these growth regulators has been extensively researched across different crops, showing notable enhancements in plant growth and yield. [4]. Research indicates that GA_3 boosts plant height, leaf expansion, and head development, whereas NAA supports root growth and increases head weight. [5,6]. Research indicates that cabbage shows a positive response to foliar applications of GA_3 and NAA, resulting in increased leaf count and enhanced marketable yield. [7,8]. Drobek M. [9]

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discovered that applying GA_3 at 60 ppm and NAA at 80 ppm produced the highest yield of cabbage heads.. Similarly, PAINKRA, B. [8] reported the highest yield when GA_3 was applied at 50 ppm, with NAA at 50 ppm closely following. Other studies suggest that GA_3 at 100 ppm yields the best results for cabbage production [10,11], while maximum head yield was also reported with NAA at 50 ppm. Although promising results have been observed in other regions, there is a lack of research on the effectiveness of these growth regulators in Bangladesh, emphasizing the need for further studies. This study assessed the effects of GA_3 and NAA on cabbage and identified their optimal concentrations for maximizing growth and yield.

Materials and Methods

Location and Study Period

The study was conducted at the Horticulture Farm of Bangladesh Agricultural Research Institute (BARI) in Joydebpur, Gazipur, from October 2016 to March 2017. It aimed to evaluate the effects of gibberellic acid (GA_3) and naphthalene acetic acid (NAA) on the growth and yield of cabbage (Brassica oleracea var. capitata).

Soil and Climatic Conditions

The experimental field had sandy clay loam soil with a pH of approximately 6.0, belonging to the Chita soil series (AEZ-28). The climate was subtropical, with heavy rainfall between May and September, followed by a dry period for the rest of the year.

Planting Material and Treatments

The test variety used was 'Atlas-70' cabbage, sourced from Siddik Bazaar, Gulistan, Dhaka. The experiment included eight treatments:

- T0: Control (distilled water)
- T1: 50 ppm GA_3
- T2: 75 ppm GA_3
- T3: 100 ppm GA_3
- T4: 40 ppm NAA
- T5: 60 ppm NAA
- T6: 80 ppm NAA
- T7: 100 ppm NAA

Study Design and Field Layout

The experiment used a Randomized Complete Block Design (RCBD) with three replications. It involved 24 plots (1.8 m × 2 m) with 50 cm × 60 cm plant spacing. Blocks were separated by 0.75 m, and plots within blocks had 0.5 m spacing.

Land Preparation and Fertilizer Application

The field was plowed, exposed to sunlight for a week, and leveled. Cinocarb 3G insecticide (4 kg/ha) was applied to control soil-borne pests. Fertilizers were applied following Islam et al. (2004) recommendations:

- Cow dung: 10 t/ha (basal dose)
- Urea: 350 kg/ha (split into three applications at 10, 30, and 50 DAT)
- TSP: 250 kg/ha (basal dose)
- MoP: 300 kg/ha (one-third basal, remainder in three split doses)

Growth Regulator Preparation and Treatment Application

A 1000 ppm GA_3 stock solution was prepared, diluted to obtain 50 ppm, 75 ppm, and 100 ppm solutions, and applied using a mini hand sprayer at 30 and 45 days after transplanting. A similar method was followed for NAA solutions.

Seedling Raising and Transplanting

Cabbage seedlings were raised at Olericulture Division, HRC, BARI, Gazipur, on 3 m × 1 m seedbeds. Decomposed cow dung (5 t/ha), 200 g TSP, and 150 g MoP were applied. Seeds were sown on November 26, 2016, and transplanted at 27 days old (December 22, 2017).

Intercultural Operations

- Gap Filling: Damaged seedlings were replaced within 7 days of transplanting.
- Weeding: Performed at 15, 30, 45, and 60 DAT.
- Earthing Up: Conducted at 20 and 60 DAT to enhance root support.
- Irrigation: Applied every 7 days; extra watering was provided in early growth stages.
- Pest and Disease Control: Darsban 29 EC (3%) was applied for cutworm control; Rovral (2 g/L water) was used against *Alternaria* leaf spot.
- Bird Control: Metallic containers were struck to deter nightingale birds from damaging cabbage heads.

Harvesting and Data Collection

Cabbage was harvested between February 28 and March 8, 2017, based on head compactness. Data were collected from five randomly selected plants per plot, while total yield was measured on a per-plot basis.

Recorded Parameters

- Plant height (cm),
- Number of leaves plant^{-1}(folded)
- Number of leaves plant^{-1}(unfolded)
- Total Number of leaves plant^{-1}
- Days to head formation & Days to head maturity
- Thickness of head and Diameter of head
- Head yield plot^{-1} /Head yield /(t ha^{-1}) % yield increase over control

Data Processing and Analysis

Data were analyzed using ANOVA in Statistics 10.0, and mean comparisons were conducted using Duncan's Multiple Range Test (DMRT) at a 5% significance level.

Result and Discussion

Plant height

The application of GA_3 and NAA has been shown (Fig 1) to significantly influence plant height in cabbage cultivation. In a study evaluating various concentrations of these plant growth regulators, the tallest plants were observed by applying of 75 ppm GA_3, reaching a height of 23.00 cm. This was statistically comparable to treatments with 50 ppm GA_3, 100 ppm GA_3, and 60 ppm NAA. In contrast, the shortest plants, measuring 17.25 cm, were recorded in the control group, which did not receive any growth regulator. The increase in plant height resulting from GA_3 and NAA treatments can be attributed to their roles in modulating physiological processes such as cell elongation and division, thereby promoting enhanced vegetative growth. GA_3, in particular, stimulates these processes in the sub-apical meristem [12]. Similarly, research on flowering Chinese cabbage demonstrated that exogenous application of GA_3 upregulated the expression of *SOC1* genes, which are associated with bolting and stem elongation, contributing to increased plant height [13].

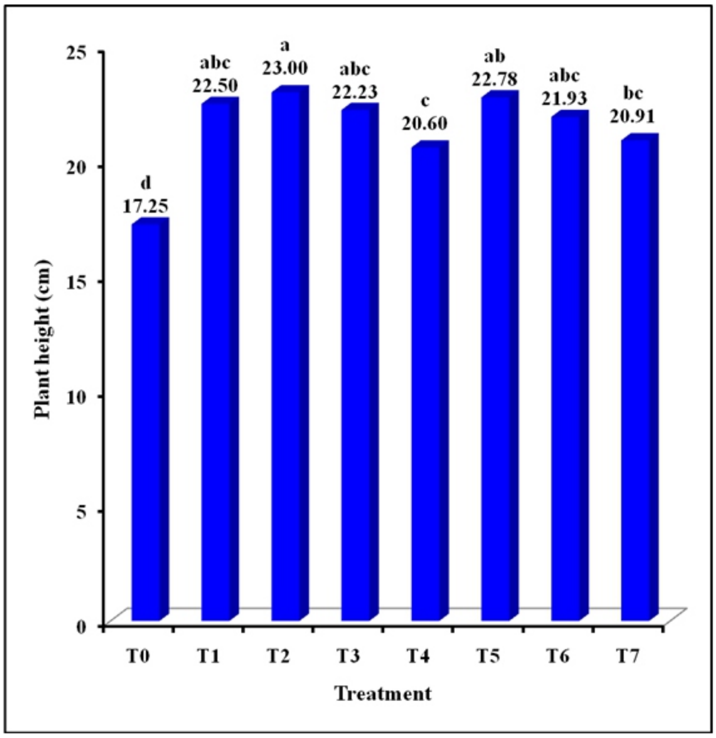

Fig. 1 Impact of GA 3 and NAA on height of cabbage plant

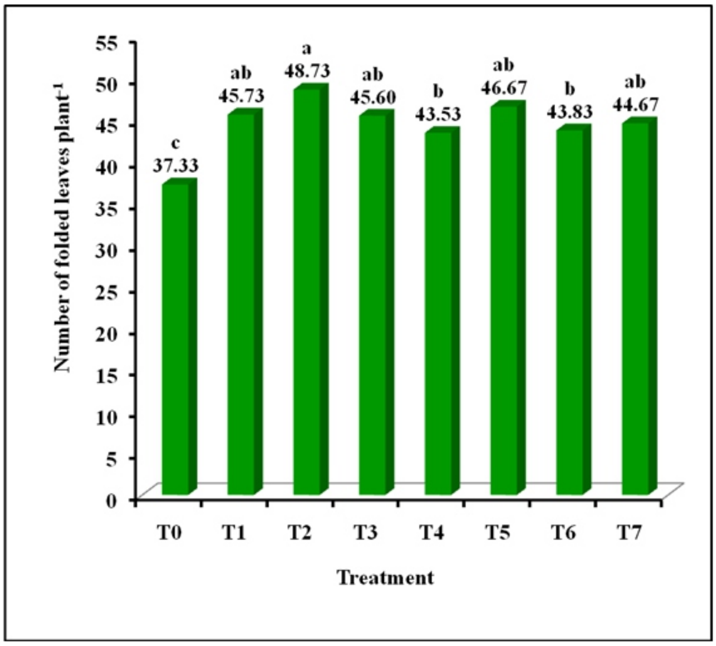

Fig. 2 Impact of GA 3 and NAA on number of leaves per plant of cabbage (folded).

Plant number of leaves-1 (unfolded)

The application of gibberellic acid (GA_3) and naphthalene acetic acid (NAA) significantly influenced the number of unfolded leaves per cabbage plant (Fig. 3). The highest number (13.60) was recorded with 75 ppm GA_3, statistically similar to 50 ppm GA_3, 100 ppm GA_3, and 60 ppm NAA treatments. The control group showed the lowest number (11.27). These findings support earlier studies, such as Prodhan et al. [12], who reported increased seed production in cauliflower with GA_3 application, highlighting its role in promoting flowering, stem elongation, and vegetative growth. Similarly, NAA, an auxin, has been noted to enhance cell division and expansion, contributing to greater leaf formation [14].

Number of leaves plant-1 (folded)

Various concentrations of GA_3 and NAA significantly influenced the number of folded leaves per cabbage plant at harvest. (Fig. 2). The greatest number of folded leaves per plant (48.73) was observed in treatment T2 (75 ppm GA_3), which was statistically comparable to treatments T1, T3, T5, and T7. Conversely, the control group (T0), where no plant growth regulators were applied, recorded the lowest number of folded leaves (37.33). The rise in the number of folded leaves under GA_3 and NAA treatments is likely due to their stimulation of key physiological processes like cell division and elongation, which promote vegetative growth and overall plant development.It was reported that foliar application of GA_3 at 200 ppm in cauliflower significantly improved seed production compared to NAA and other growth regulators, highlighting GA_3's role in promoting physiological activities such as flowering and stem elongation that may indirectly affect leaf development[12]. Furthermore, research by Sosnowski et al. [14] emphasized the role of auxins and cytokinins in stimulating cell division and expansion, with NAA, a synthetic auxin, shown to promote both root and shoot growth,

there by potentially increasing leaf production per plant.

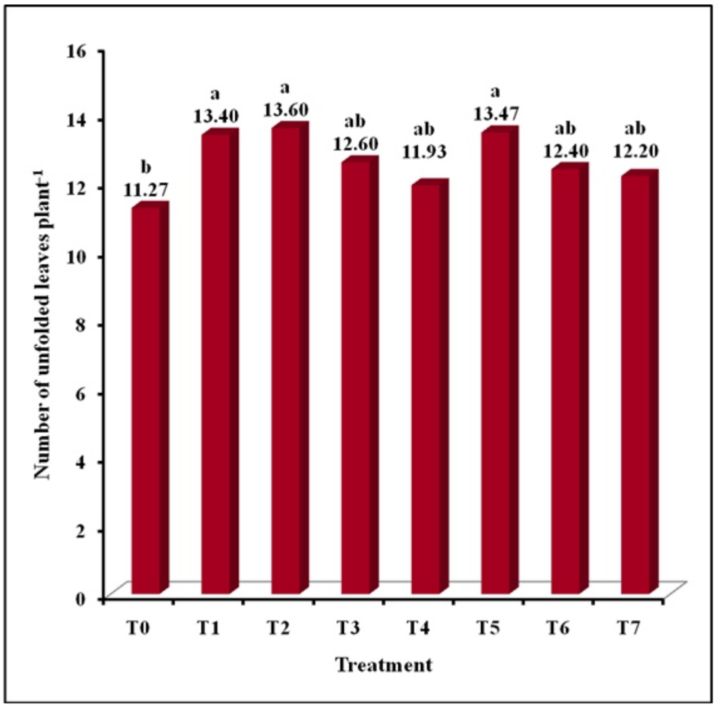

Fig. 3. Impact of GA_3 and NAA on number of leaves per plant of cabbage (unfolded)

Total Number of leaves plant^{-1}

The application of gibberellic acid (GA_3) and naphthalene acetic acid (NAA) significantly affected the total number of leaves per cabbage plant at harvest. The highest leaf count (62.33) was recorded with 75 ppm GA_3 (T2), followed by 60 ppm NAA (60.13), 50 ppm GA_3 (59.13), 100 ppm GA_3 (58.20), and 80 ppm NAA (56.87). The control group (T0) showed the lowest number (48.60). These results align with previous findings that exogenous GA_3 enhances vegetative traits (Fig. 4), including leaf production. Similarly, NAA, by regulating cell division and expansion, also promotes leaf development, contributing to improved plant growth and vigor.

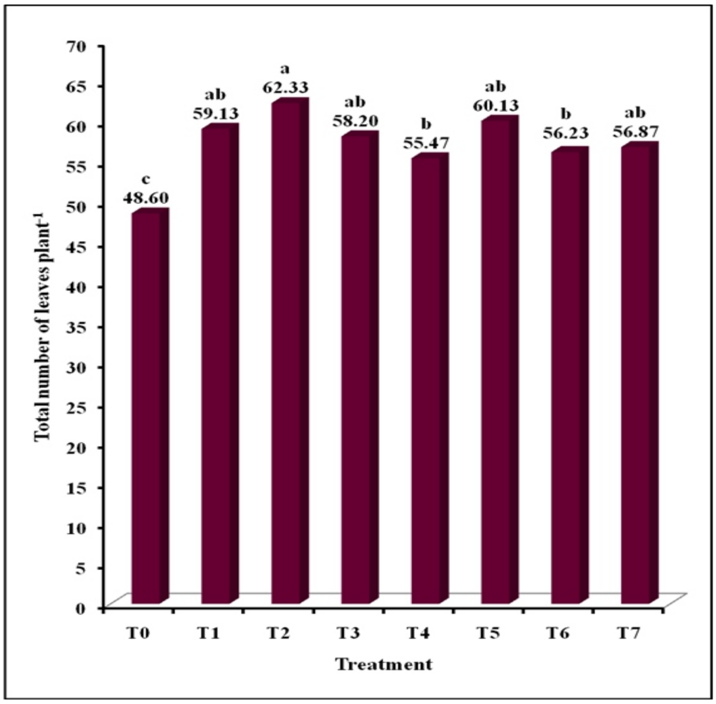

Fig. 4. Effect of GA_3 and NAA on total number of leaves per plant of cabbage

Days to head formation Days to head maturity

The application of gibberellic acid (GA_3) and naphthalene acetic acid (NAA) at different concentrations significantly affected the timing of head formation and maturity in cabbage (Table 1). The control (T0) required the longest time for head initiation (40.50 days) and maturity (79.46 days), while 75 ppm GA_3 (T2) achieved the shortest durations (35.20 and 70.42 days, respectively). These results align with previous studies, such as Pooja Chanwala et al. [15], who reported that GA_3 accelerates developmental transitions by influencing the apical meristem. The combined use of GA_3 and NAA also promotes faster growth, earlier head formation, and higher yield through enhanced cell division and elongation [16].

Table1. Effect GA_3 and NAA on days to head formation and Days to maturity of cabbage

Treatment	Days to head formation		Days to maturity	
T_0	40.25	a	79.46	a
T_1	36.65	ab	72.22	bc
T_2	35.42	b	70.42	c
T_3	35.20	b	72.62	bc
T_4	36.70	ab	74.64	abc
T_5	35.35	b	70.45	c
T_6	36.82	ab	73.82	abc
T_7	36.90	b	77.25	ab
CV (%)	5.18		4.16	

Thickness of head and Diameter of head

The application of gibberellic acid (GA_3) and naphthalene acetic acid (NAA) at different concentrations significantly influenced cabbage head morphology, particularly head thickness and diameter (Table 2). The highest head thickness (14.23 cm) was recorded with 75 ppm GA_3 (T2), statistically similar to all treatments except the control (11.63 cm). Similarly, the largest head diameter (22.60 cm) was observed with 75 ppm GA_3, followed by treatments with 60 ppm NAA, 50 ppm GA_3, 80 ppm NAA, and 100 ppm NAA. The control group had the smallest diameter (17.60 cm). These results align with earlier findings, such as those by Grafmüller et al. [17], showing that GA_3 enhances vegetative growth and yield traits by promoting processes like stem elongation and flowering in Brassica species.

Table 2 Effect of GA 3 and NAA on thickness and diameter of head of cabbage

Treatment	Thickness of head (cm)		Diameter of head (cm)	
T_0	11.63	b	17.60	c
T_1	13.97	a	21.69	ab
T_2	14.23	a	22.60	a
T_3	13.53	ab	21.80	ab
T_4	13.00	ab	20.34	b
T_5	13.90	a	22.42	ab
T_6	13.49	ab	21.09	ab
T_7	13.43	ab	20.70	ab
CV (%)	7.41		6.42	

Head yield plot^{-1} /Head yield /(t ha^{-1}) % yield increase over control

The application of gibberellic acid (GA_3) and naphthalene acetic acid (NAA) significantly influenced cabbage head yield (Table 3). The highest yield per plot (26.82 kg) and per hectare (102.40 t ha^{-1}) were recorded with 75 ppm GA_3 (T2), closely followed by 50 ppm GA_3 (25.93 kg and 89.63 t ha^{-1}). The control (T0) produced the lowest yields (20.10 kg and 68.21 t ha^{-1}). Yield increases over the control were 33.39%, 23.90%, and 21.83% with 75 ppm GA_3, 50 ppm GA_3, and 60 ppm NAA, respectively. These results are consistent with earlier studies showing that GA_3 promotes vegetative growth, stem elongation, flowering, and biomass accumulation, all contributing to higher yield in Brassica crops.

Table 3. Effect of GA 3 and NAA on yield and yield of cabbage

Treatment	Head yield (kg plot^{-1})	Head yield (t ha^{-1})	% yield increase over control
T_0	26.04 e	68.21 d	-
T_1	33.93 ab	89.63 ab	23.90
T_2	36.82 a	102.40 a	33.39
T_3	28.80 cde	80.34 bcd	15.10
T_4	27.24 de	72.32 cd	5.68
T_5	31.39 bc	87.26 abc	21.83
T_6	30.44 cd	84.61bcd	19.38
T_7	29.33 cd	75.73 bcd	9.93
CV (%)	5.71	10.67	-

Conclusion

The study showed that applying GA_3 and NAA through foliar treatment notably enhances the growth and yield of cabbage. Among all treatments, 75 ppm GA_3 proved most effective, enhancing vegetative traits, advancing maturity, and increasing yield by over 33% compared to the control. These findings support the use of plant growth regulators, especially GA_3 at optimal concentrations, to bridge the yield gap and boost cabbage production in Bangladesh.

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