Article

Growth and quality yield of purple cabbage influenced by nutrient sources and NAA

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Abstract: The experiment was conducted at Horticultural Farm, Sher-e-Bangla Agricultural University, during the period from October 2018 to February 2019 to study the application of nutrient sources interaction with NAA for higher growth and quality yield of purple cabbage. The experiment consists of two factors. Factor A: F₀: control, F₁: vermicompost (10 t/ha), F₂: N₁₈₀kg·ha⁻¹ P₆₆kg·ha⁻¹ K₇₅kg·ha⁻¹ and F₃: ½ vermicompost (5t. ha⁻¹) + N₉₀kg·ha⁻¹ P₃₃kg·ha⁻¹ K₃₈kg·ha⁻¹ Factor B: four levels of NAA, N₀: 0 ppm, N₁: 20 ppm, N₂: 40 ppm and N₃:80 ppm was used for the present study. The experiment was carried out in RCBD with three replications. Results showed that the highest yield of purple cabbage (27.38 t/ha) was found from the mixture of vermicompost and NPK treatment and the lowest yield (16.05 t/ha) was found from the control treatment. For different levels of NAA, the highest yield of purple cabbage (25.39 t/ha) was found from the N2 (40 ppm) treatment and the lowest yield (15.41 t/ha) was found from N0 (control) treatment. In the case of combined effect, the highest yield of purple cabbage (36.80 t/ha) was obtained from F3N2 (½ vermicompost and ½ NPK doses + 40 ppm NAA) treatment combination, and the lowest yield (6.64 t/ha) was found from F0N0 (control) treatment combination.

Keywords: growth; yield; nutrient source; NAA; purple cabbage

1. Introduction

Purple cabbage (Brassica oleracea var. Capitata L.), one of the principal vegetable Cole crops, is grown all across the nation. It is an herbaceous, biennial, dicotyledonous plant that has a short stem and a dense pile of leaves on it that are often green but can be red or purple in some kinds. When it is in an immature stage, however, a compact and globular cluster that resembles a cabbage head forms (Anon. 2011; Ahmed et al., 2018). Consumption of purple cabbage has significantly increased in recent years due to its remarkable health-enhancing capabilities and a variety of advantageous sensory attributes (Wojciechowska et al., 2007). Purple cabbage stands out for having the highest antioxidant capacity of any vegetable, much surpassing that of spinach, broccoli, onion, or tomato (Proteggente et al., 2002). Plant genotype and culture circumstances, as well as the environment, all affect how many physiologically active chemicals are present in a plant. Due to the ongoing use of high analysis chemicals and unbalanced fertilizer, as well as the minimal inclusion of plant growth regulators, the productivity of cabbage, is expected to decline in various types of soils. Although they are different applications, the foliage would undoubtedly increase crop productivity and soil fertility over higher production of cabbage as a result of careful fertilizer application, appropriate cultural management, etc.
When a plant receives the right quantity of nitrogen, there is a tendency for the number and size of leaf cells to increase, leading to an overall rise in leaf production (Morton and Watson, 1948). The source of nutrients is one of several variables that affect the growth of every crop. The proper application of manure and fertilizer is related to the productivity and quality of cabbage. Nutrients can be applied through two sources: inorganic and organic. The increased usage of inorganic fertilizers raises environmental and health concerns. Organic nutrient sources are palatable and less detrimental to the ecosystem. To decrease the economic return, avoid health hazards, and support sustainable agriculture, the use of renewable sources of nutrients should be encouraged. On the other hand, a careful balance of organic and inorganic nutrients may help to obtain a solid financial return while maintaining the soil's favorable conditions.

Auxin, one of the growth regulators, including NAA (Naphthalene Acetic Acid), causes the plant cell to enlarge. When NAA is applied, morphological traits such as plant height, the number of leaves, head diameter, head thickness, and head weight are stimulated (Dev et al., 2020). Therefore, it was decided that it was important to determine the dose of NAA that would be most beneficial in stimulating the development and yield of purple cabbage (Thapa et al., 2013). Due to increased agricultural intensification and indiscriminate use of chemical fertilizers, soil organic matter is generally declining dramatically in Bangladesh (Muhibullah et al., 2005). By encouraging the use of organic fertilizer while discouraging the use of inorganic fertilizer, this discovery could help Bangladesh produce sustainable crops.

2. Materials and Methods

2.1. Experimental site

The present study was conducted in the Horticultural Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. The location of the site is 23° 74’ N latitude and 90° 35‘ E longitude with an elevation of 8.2 meters from sea level.

2.2. Soil characteristics

The general soil type of the experimental field is deep red-brown terrace soils, and it is a part of the Tejgaon series under the Madhupur Tract (AEZ-28) of the agro-ecological zone. Before the study began, dirt was collected from various locations in the field at a depth of 0–15 cm to create a composite sample. At the Soil Resources Development Institute (SRDI), Khambari, Farmgate, Dhaka, the collected soil was air-dried, ground, and put through a 2 mm screen before being examined for certain significant physical and chemical characteristics. The soil had a sandy loam texture, a pH of 5.9, an organic matter capacity of 0.78 percent, and was made up of 28% sand, 42% silt, and 30% clay.

2.3. Planting materials

The test crop used in the experiment was the purple cabbage hybrid variety Ruby King and the seeds were collected from Siddique Bazar, Dhaka.

2.4. Treatments of the experiment

The experiment consists of two factors. Factor A: F0: control, F1: Vermicompost (10 t/ha), F2: N180 kg/ha-1; P66 kg/ha-1; K75 kg/ha-1 and F3: ½ vermicompost (5 t/ha-1) + N90 kg/ha-1; P33 kg/ha-1; K38 kg/ha-1 Factor B: four levels of NAA, N0: 0 ppm, N1: 20 ppm, N2: 40 ppm and N3: 80 ppm were used for the present study.

2.5. Preparation of NAA solution

The solution of NAA 20, 40, and 80 ppm was prepared by separately weighing each concentration using an electronic balance before placing it in a different test tube. To dissolve NAA, ethyl alcohol that is 99.99% pure was applied to the test tube. 25 mg are dissolved in 1 ml of KOH (1N), and the remaining 25 ml are then obtained by boiling distilled water. Store the stock (solution) in the fridge. To create 1 L of MS basal medium containing 1 mg/L NAA, add 1 ml of the aforementioned solution to 1 L of MS medium before autoclaving.

2.6. Raising of seedlings

The purple cabbage seedlings were raised in a seedbed of 3 meters by 1 meter at the Horticultural Farm, SAU, in Dhaka. The seedbed's soil was carefully plowed, turned into loose, friable dried masses, and given good tilth. Any previous crop's weeds, stubbles, and dead roots were eliminated. Fungicide was used to control the disease that causes damping-off. On October 18, 2018, ten (10) grams of seeds were placed in each seedbed. The seeds
were sown, and the finished, light soil was spread over them. After germination, a bamboo mat (chatai) was placed over the seedbed to provide shading, shielding the tiny seedlings from the sun's rays and heavy downpours. To provide seedlings with the perfect environment, light watering and weeding are done as needed.

2.7. Preparation of the main field
On September 5, 2018, using a power tiller, the experiment's chosen plots were unlocked and exposed to the sun for a week. In order to prepare the ground for transplanting the seedlings, a country plow was used to cross-plow the area five times. The land was free of any weeds, stubbles, and leftovers. A satisfactory tilth was finally attained.

2.8. Transplanting
On the afternoon of November 15, 2018, the seedlings were transplanted in accordance with the design plan. The distances between plants and rows were kept at 40 and 60 cm, respectively. Seedlings that were 24 days old, healthy, and of uniform size were chosen. To reduce harm to the seedlings' roots, the seedbed was irrigated one hour before the seedlings were uprooted. In each unit plot, twelve plants were transplanted. After transplantation, the plants were immediately given water. Watering was kept up until the seedlings were established, which took six days.

2.9. NAA application
For more growth and productivity, NAA hormone was given twice to the purple cabbage plant. At 30 and 45 days old, it was properly treated with a hand sprayer over the entire plant. Several meticulous measurements should have been taken when the hormone was sprayed. For a good atmosphere, the hormone is always sprayed in the late afternoon.

2.10. Data collection
For growth and development characteristics of plants were made on five randomly chosen plants for each treatment in each replication at various growth stages and ages in order to prevent border effects. For the purpose of documenting the specifics of observations, the chosen plants were tagged.

2.11. Fe determination
The Bangladesh Council of Scientific and Industrial Research's Institute of Food Science and Technology evaluated the iron level of cabbage using a UV-Spectrophotometer (BCSIR). It was calculated as mg/100 g.

2.12. β-carotene determination
The Bangladesh Council of Scientific and Industrial Research's Institute of Food Science and Technology evaluated the beta carotene content of cabbage using a UV spectrophotometer (BCSIR). G/100 gram was used to measure it.

2.13. Statistical analysis
The SPSS Statistics program, version 24, was used to statistically process the data using ANOVA. The mean value for the treatments was identified, and the F (variance ratio) test was run to calculate the variance for each character. Duncan's multiple range tests at P ≤ .05. were used to get the mean separation. Along with the mean values, standard error calculations and results were also provided.

3. Results and Discussion
3.1. Canopy of plant
The canopy of purple cabbage varied statistically due to the different levels of NPK and vermicompost at 20, 40, and 60 DAT, respectively. Treatment F3 gave the maximum plant canopy (765.03 cm², 1250 cm², and 2863.85 cm²) while the control treatment gave the minimum (608.90 cm², 994.05 cm², and 2055.88 cm²) plant canopy at 20 DAT, 40 DAT, and 60DAT respectively (Table 1). The results indicated that the combined mixture of vermicompost and NPK doses helps to increase plant canopy by developing vegetative growth and the highest plant canopy was recorded in that condition. The plant canopy of purple cabbage varied significantly due to the different levels of NAA at 20, 40, and 60 DAT respectively (Figure 1). At N2 treatment gave the maximum plant canopy (806.92 cm², 1127.38 cm², and 2764.69 cm²) and the minimum plant height (555.08 cm², 1086.83 cm², and 2308.15 cm²) were observed in N0 treatment at 20 DAT, 40 DAT, and 60 DAT respectively. The combined
effect of different nutrient sources and NAA showed statistically significant variation in terms of plant canopy at 20, 40, and 60 DAT (Table 2). The maximum plant canopy (926.60 cm², 1464.90 cm², and 3496.40 cm²) was observed from F₃N₂ and the minimum plant canopy (502.73 cm², 818.13 cm², and 1699.13 cm²) was found from F₀N₀ treatments at 20, 40, and 60 DAT respectively. Vermicompost increases the vegetative growth and NAA increases the leaf canopy. Vermicompost and inorganic fertilizer together encourage plant growth because inorganic fertilizer gives the cabbage a quick release of nutrients (Rai et al., 2013). At the same time, the plant receives nutrients during crop growth due to the use of vermicompost, which progressively releases nutrients to the plant. Sharma (2000) discovered that combining the use of organic and inorganic fertilizers considerably increased vegetative growth.

Table 1. Effect of fertilizer on plant canopy on different days after transplanting (DAT) of purple cabbage.

| Treatment | CANOPY PER PLANT AT |
|-----------|---------------------|
|           | 20DAT | 40DAT | 60DAT |
| F₀        | 608.90±28.79b | 994.05±47.67b | 2055.88±118.73b |
| F₁        | 723.28±27.10a | 1104.65±26.21ab | 2359.33±92.22b |
| F₂        | 734.90±42.00a | 1223.12±55.70a | 2895.13±110.84a |
| F₃        | 765.03±35.72a | 1250.14±58.72a | 2863.85±131.31a |
| Significance level | ** | *** | *** |

Figure 1. Effect of NAA on plant canopy on different days after transplanting (DAT) of purple cabbage.
Table 2. The combined effect of nutrient sources and NAA on plant canopy of purple cabbage.

| Treatment Combination | Canopy/plant (cm²) |
|-----------------------|--------------------|
|                       | 20DAT              | 40DAT              | 60DAT              |
| F₀N₀                  | 502.73±33.21e      | 818.13±34.19d      | 1699.13±85.53g     |
| F₀N₁                  | 647.47±24.57cd     | 1095.47±74.37bcd   | 2340.27±234.29def  |
| F₀N₂                  | 666.13±40.13cde    | 1066.27±97.76bcd   | 2154.87±195.33eefg |
| F₀N₃                  | 619.27±82.72cde    | 996.33±102.56cde   | 2029.27±316.96fg   |
| F₁N₀                  | 686.07±13.74bcde   | 1082.67±65.89bcde  | 2423.07±287.77cf   |
| F₁N₁                  | 687.87±50.31bcd    | 1170.73±33.05bc    | 2304.93±24.57dg    |
| F₁N₂                  | 774.53±88.47abc    | 1058.87±66.78bcde  | 2198.07±146.47efg  |
| F₁N₃                  | 744.67±52.43bc     | 1106.33±41.70bcd   | 2511.27±232.72cf   |
| F₀N₁                  | 751.13±85.95bc     | 1292.67±176.94abc  | 2612.93±187.15bf   |
| F₀N₂                  | 564.87±35.82de     | 1227.20±104.51abc  | 2744.67±148.98be   |
| F₀N₃                  | 860.47±36.69ab     | 1319.47±42.39ab    | 3209.43±252.08ab   |
| F₁N₁                  | 763.13±76.94abc    | 1053.13±51.98bcd   | 3013.47±204.95abc  |
| F₁N₂                  | 669.00±49.30cde    | 1179.80±146.74abc  | 2497.47±173.64cf   |
| F₁N₃                  | 674.80±17.66cde    | 1111.27±52.38bcd   | 2566.00±154.01cf   |
| F₂N₀                  | 926.60±18.40a      | 1464.90±78.36a     | 3496.40±31.40a     |
| F₂N₁                  | 789.73±54.30abc    | 1244.60±101.19abc  | 2895.53±111.52bcd  |

Significance level: *** *** ***

In a column having a similar letter (s) are statistically identical and those having a dissimilar letter (s) differ significantly as per the 0.05 level of probability analyzed by DMRT.

3.2. The whole weight of cabbage

Purple cabbage was 1st harvested 74 days after transplanting. The whole weight of purple cabbage means the weight of the harvested head with unfolded leaves. The whole weight can be varied statistically due to the different levels of NPK and vermicompost at the different times of harvest. F₃ treatment gave maximum weight (891.32 gm) while control treatment gave minimum weight (551.28 gm) (Table 3). The whole weight of cabbage varied significantly due to the different levels of NAA. At 40ppm NAA dose gave maximum weight (831.41 gm) of cabbage and it was observed in N₀ treatment at 40DAT. It has been discovered that the use of mineral fertilizer and vermicompost increases soil quality, moisture content, microbial activity, and proper aeration. As a result, plant nutrients are more readily available to the plant, resulting in better head growth and development, which ultimately increases total yield. Additionally supporting the outcome of the current research was Rai et al. (2013). The findings of this study agreed with those of Souza et al. (2008) and Vimala (2006).

3.3. Head fresh weight

The head fresh weight of purple cabbage means the weight of the harvested head without unfolded leaves. The head fresh weight can be varied statistically due to the different levels of NPK and vermicompost at the different times of harvest. F₂ treatment gave the maximum weight (657.12 gm) while F₀ treatment gave the minimum weight (385.28 gm) (Table 3). The result found the maximum plant spread, head circumference, height, and total marketable yield of cabbage (Ghuge et al., 2007). The head weight of cabbage varied significantly due to the different levels of NAA. The treatment 40 ppm NAA dose gave the maximum head weight (609.26 gm) of cabbage and it was observed in N₂ treatment and minimum weight (369.92 gm) was observed in N₀ treatment at the different times of harvest (Table 3). The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of the head weight of purple cabbage at different harvesting times (Table 4). At harvesting time maximum head weight (883.07 gm) was observed from F₃N₀; the treatment and the minimum weight (159.43 gm) was found from the F₀N₀ treatment. Its balanced nutrient...
composition may have contributed to the best cabbage head weight, head length, and head width results obtained from the application of vermicompost with chemical fertilizer. The vermicompost with the lowest C/N ratio supported rapid decomposition and quick nitrogen release for crop absorption and greater head yield parameters. These findings were supported by Ijoyah and Sophie (2009), who discovered that the application of chemical fertilizer in conjunction with organic manure increased cabbage output. This may be the reason for the cabbage crop's quick release and absorption of nutrients and, as a result, higher output of cabbage heads.

3.4. Unfolded leaf number
The unfolded leaf number of purple cabbage was counted after the harvested cabbage. The unfolded leaf number can be varied statistically due to the different levels of NPK and vermicompost at the different times of harvest. F2 treatment gave the maximum leaf number as well as unfolded leaf number (9.67) while the control treatment gave the minimum (7.42) (Table 3). The unfolded leaf number of cabbage varied significantly due to the different levels of NAA at harvest time. At 40ppm NAA dose gave the maximum unfolded leaf number (9.00) of cabbage and it was observed in N2 treatment and the minimum number (7.92) was observed in N0 treatment at a different time of harvest (Table 3). The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of unfolded leaf number of purple cabbage at different harvesting times (Table 4). At harvesting time average maximum cabbage unfolded leaf number (10.33) was observed from F2N2 (NPK doses + 40ppm NAA) and the minimum number (4.67) was found from F0N0 (No nutrient sources and No NAA dose i.e. control condition treatment).

3.5. Unfolded leaf weight
The weight of unfolded leaves of purple cabbage was done after the harvest of the cabbage. The weight of unfolded leaves can be varied statistically due to the different levels of NPK and vermicompost at the different times of harvest. The recommended dose of NPK treatment gave maximum weight (269.40 gm) by thickening the leaves while the control treatment gave the lowest weight (166.00gm) (Table 3). The weight of unfolded leaves of purple cabbage was done after the harvest of the cabbage. The treatment 40 ppm NAA dose gave the maximum leaf weight (222.15 gm) of cabbage and it was observed in N2 treatment and minimum weight (209.58 gm) was observed in N1 treatment at the different times of harvest (Table 3). The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of unfolded leaf weight of purple cabbage at different harvesting times (Table 4). At harvesting time average maximum unfolded leaf weight (302.93 gm) was observed from F2N2 (NPK doses + 40ppm NAA) and the minimum weight (147.63 gm) was found from F0N1 (No nutrient sources and 20 ppm NAA dose i.e. control condition) treatment.

Table 3. Effect of nutrient sources and NAA on whole weight, head fresh weight, unfolded leaf number and unfolded leaf weight of purple cabbage.

| Treatment | Whole Weight(g) | Head Fresh Weight(g) | Unfolded Leaf Number | Unfolded Leaf Weight(g) |
|-----------|-----------------|----------------------|----------------------|------------------------|
| F0        | 551.28±44.5b    | 385.28±44.06b        | 7.42±0.62b           | 166.00±17.52c          |
| F1        | 630.50±34.7b    | 436.85±34.05b        | 8.58±0.67ab          | 193.65±21.60bc         |
| F2        | 825.81±30.66a   | 556.41±19.61a        | 9.67±0.31a           | 269.40±15.53a          |
| F3        | 891.32±49.19a   | 657.12±49.05a        | 8.58±0.34ab          | 234.20±14.33ab         |
| N0        | 580.30±57.77b   | 369.92±44.06b        | 7.92±0.76            | 210.38±21.17           |
| N1        | 709.75±39.89ab  | 500.17±27.81a        | 8.75±0.25            | 209.58±18.40           |
| N2        | 831.41±58.96a   | 609.26±54.97a        | 9.00±0.46            | 222.15±21.01           |
| N3        | 777.45±44.03a   | 556.30±36.54a        | 8.58±0.60            | 221.14±23.27           |

In a column having a similar letter (s) is statistically identical and those having a dissimilar letter (s) differ significantly as per the 0.05 level of probability analyzed by DMRT.
Table 4. Combined effect of nutrient sources and NAA on whole weight, head fresh weight, unfolded leaf number and unfolded leaf weight of purple cabbage.

| Treatment Combination | Whole Weight of Cabbage (g) | Head Fresh Weight (g) | Unfolded Leaf Number | Unfolded Leaf Weight (g) |
|-----------------------|----------------------------|-----------------------|----------------------|-------------------------|
| F₀N₀                  | 314.70±14.65f              | 159.43±43.65a         | 4.67±0.67            | 155.27±39.83            |
| F₀N₁                  | 575.63±42.80e              | 428.00±32.48bc        | 8.33±0.33            | 147.63±34.22            |
| F₀N₂                  | 626.13±33.54de             | 430.07±13.61bc        | 9.00±0.58            | 196.07±31.36            |
| F₀N₃                  | 688.67±6.74cde             | 523.63±50.68bf        | 7.67±1.45            | 165.03±48.30            |
| F₁N₀                  | 552.23±122.82e             | 362.70±79.96b         | 8.00±2.08            | 189.53±58.36            |
| F₁N₁                  | 636.57±55.26de             | 432.67±38.84bc        | 8.33±0.67            | 203.90±37.30            |
| F₁N₂                  | 684.62±38.43cde            | 512.56±78.91be        | 8.33±1.45            | 172.07±48.83            |
| F₁N₃                  | 648.57±46.94de             | 439.47±75.80abc       | 9.67±1.45            | 255.94±19.60            |
| F₂N₀                  | 740.60±9.72be              | 484.66±9.89bcde       | 9.67±0.33            | 242.57±30.78            |
| F₂N₁                  | 784.47±11.53bcd            | 541.90±24.90cf        | 9.00±0.58            | 242.57±30.78            |
| F₂N₂                  | 914.30±14.68b              | 611.37±7.04ef         | 10.33±0.67           | 302.93±12.46            |
| F₂N₃                  | 863.87±105.45bc            | 587.71±54.86bc        | 9.67±0.88            | 276.16±52.74            |
| F₃N₀                  | 713.67±24.85cde            | 472.90±15.50be        | 9.33±0.33            | 240.77±35.28            |
| F₃N₁                  | 842.33±82.07bc             | 598.10±57.34def       | 9.33±0.33            | 244.23±29.32            |
| F₃N₂                  | 1100.60±46.52a             | 883.07±42.32g         | 8.33±0.67            | 217.53±36.37            |
| F₃N₃                  | 908.69±68.48b              | 674.42±56.80f         | 7.33±0.67            | 234.27±29.69            |

Significance level  *** Non-significant Non-significant

In a column having a similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per the 0.05 level of probability analyzed by DMRT.

3.6. Head length
The head length of purple cabbage varied statistically due to the different levels of NPK and vermicompost at harvest time. The mixture of vermicompost and NPK doses (F₃) treatment gave the maximum length (9.95 cm) while the control (F₀) treatment gave the minimum head length (4.73 cm) (Table 5). The results indicated that the mixture of vermicompost and NPK doses help to increase the length of the cabbage head and the broader head length was recorded in that condition. The head length of cabbage varied significantly due to the different levels of NAA after harvest. 40ppm NAA dose gave the maximum head length (8.87 cm) and it was observed in N₂ treatment and the minimum length (7.31 cm) was observed in N₀ treatment (Table 5). The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of the head length of purple cabbage (Table 6). The maximum head length (10.57 cm) was observed from F₃N₂ and the minimum head length (3.43 cm) was found from the F₀N₀ treatment. Mebrahtu and Solomun (2018), and Kedino et al. (2009) all indicated greater head diameters with the combined application of organic and inorganic fertilizers in their studies.

3.7. Head breadth
The head breadth of purple cabbage varied statistically due to the different levels of NPK and vermicompost at harvest time. The mixture of vermicompost and NPK doses (F₃) treatment gave the maximum breadth (10.56 cm) while the control (F₀) treatment gave the minimum head breadth (7.39 cm) (Table 5). The head breadth of cabbage varied significantly due to the different levels of NAA after harvest. 40ppm NAA dose gave the highest head breadth (10.12 cm) and was observed in N₂ treatment and the lowest breadth (8.77 cm) was observed in N₀ treatment (Table 5). The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of the head breadth of purple cabbage (Table 6). The higher head breadth (11.29 cm) was observed in the F₃N₂ treatment and the shorter head breadth (6.68 cm) was found in the F₀N₀ treatment. Haque (2012) indicated greater head diameters with the combined application of organic and inorganic fertilizers in their studies.
Table 5. Effect of nutrient sources and NAA on head length, head breadth, Root length, and Stem diameter of purple cabbage.

| Treatment | Head Length (cm) | Head Breadth (cm) | Dry Weight (g) | Iron (Fe) | Beta (β) Carotene |
|-----------|------------------|------------------|----------------|-----------|------------------|
| F₀        | 4.73±0.47c       | 7.39±0.56c       | 8.50±0.26c     | 1.29±0.01d | 17.90±1.82c      |
| F₁        | 4.84±0.54b       | 8.69±0.56b       | 11.50±0.26a    | 1.38±0.02c | 38.43±3.57b      |
| F₂        | 9.87±0.06a       | 10.36±0.20a      | 9.50±0.50ab    | 1.55±0.02b | 52.38±3.21b      |
| F₃        | 9.95±0.15a       | 10.56±0.21a      | 10.00±0.43b    | 1.64±0.04a | 99.61±12.66a     |

Significance level: *** Non-significant

In a column having a similar letter (s) are statistically identical and those having a dissimilar letter (s) differ significantly as per the 0.05 level of probability analyzed by DMRT.

Table 6. Combined effect of nutrient sources and NAA on head length, head breadth, Root length, and Stem diameter of purple cabbage.

| Treatment Combination | Head Length (cm) | Head Breadth (cm) | Dry Weight (g) | Yield/ha (ton) | Iron (Fe) | Beta (β) Carotene |
|-----------------------|------------------|------------------|----------------|---------------|-----------|------------------|
| F₀N₀                  | 3.43±0.03c       | 6.68±0.48        | 8.00±0.00      | 16.84±1.82g   | 1.25±0.03g | 10.10±0.00       |
| F₀N₁                  | 3.63±0.30c       | 7.20±0.35        | 8.00±0.00      | 17.83±1.35ef  | 1.29±0.007g| 14.00±0.00       |
| F₀N₂                  | 6.13±0.29b       | 8.93±1.22        | 10.00±0.00     | 19.92±0.57ef  | 1.30±0.01fg | 23.20±0.00       |
| F₀N₃                  | 5.73±1.29b       | 6.75±1.85        | 8.00±0.00      | 21.82±2.11bf  | 1.32±0.01efg| 24.30±0.00       |
| F₀N₀                  | 6.48±1.66b       | 7.88±2.33        | 10.00±0.00     | 15.11±3.33f   | 1.32±0.01efg| 23.30±0.00       |
| F₁N₁                  | 8.92±0.49a       | 8.99±0.76        | 12.00±0.00     | 18.03±1.62ef  | 1.36±0.03efg| 32.40±0.00       |
| F₁N₂                  | 8.83±0.70a       | 9.38±0.30        | 12.00±0.00     | 21.36±3.29cf  | 1.39±0.05dg | 55.00±0.00       |
| F₁N₃                  | 9.67±0.15a       | 8.50±0.42        | 12.00±0.00     | 18.31±3.16def | 1.44±0.00cf | 43.00±0.00       |
| F₂N₀                  | 9.63±0.07a       | 9.87±0.22        | 10.00±0.00     | 20.19±0.41cf  | 1.46±0.02cde | 48.60±0.00       |
| F₂N₁                  | 10.02±0.11a      | 10.44±0.44       | 8.00±0.00      | 22.58±1.04be  | 1.51±0.05bcdf | 47.00±0.00       |
| F₂N₂                  | 9.94±0.07a       | 10.87±0.49       | 8.00±0.00      | 25.47±0.29bc  | 1.58±0.04bcf | 70.50±0.00       |
| F₂N₃                  | 9.90±0.12a       | 10.27±0.33       | 12.00±0.00     | 24.49±2.29be  | 1.63±0.01abf | 43.40±0.00       |
| F₂N₀                  | 9.71±0.18a       | 10.13±0.54       | 8.00±0.00      | 19.70±0.64cf  | 1.54±0.10bcf | 55.30±0.00       |
| F₂N₁                  | 9.74±0.07a       | 10.38±0.45       | 10.00±0.00     | 24.92±2.39bcd | 1.55±0.11bcf | 60.00±0.00       |
| F₂N₂                  | 10.57±0.03a      | 11.29±0.05       | 12.00±0.00     | 36.80±1.77a   | 1.75±0.000a | 142.50±0.00      |
| F₂N₃                  | 9.80±0.45a       | 10.44±0.33       | 10.00±0.00     | 28.10±2.37b   | 1.72±0.02a  | 140.65±0.00      |

Significance level: *** Non-significant

In a column having a similar letter (s) is statistically identical and those having a dissimilar letter (s) differ significantly as per the 0.05 level of probability analyzed by DMRT.

3.8. Yield/ha

The yield/ha of purple cabbage varied statistically due to the different levels of NPK and vermicompost at harvest time. A mixture of vermicompost and NPK doses treatment gave the maximum yield/ha (27.38 ton) and the control treatment gave the minimum yield/plot (16.05 ton) (Figure 2). The maximum yield was observed from treatment F₃. The yield of cabbage varied significantly due to the different levels of NAA after harvest. The treatment 40 ppm NAA dose gave the maximum yield (25.39 ton) and it was observed in N₂ treatment and the minimum yield was observed in N₀ treatment (15.41 ton) (Figure 3). The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of yield/ha of purple cabbage (Table 6). The maximum yield (36.80 ton) was observed from F₂N₃ and the minimum yield/ha (14.64 ton) was found from the F₀N₀ treatment. Similar to this, cabbage plants that received both organic and inorganic fertilizers improve head yield (Sharma et al., 2002). Higher fertility levels favored head cabbage onset and maturity (Kidane, 2016).
Figure 2. Effect of fertilizer on yield/ha of purple cabbage at harvest time.

Figure 3. Effect of NAA on yield/ha of purple cabbage at harvest time.

3.9. The dry weight of cabbage
The dry weight of purple cabbage varied statistically due to the different levels of NPK and vermicompost at harvest time. Vermicompost treatment gave the maximum dry weight (11.5 g) while control treatment gave the minimum dry weight (8.5 g). The maximum dry weight was observed from treatment F1 and the minimum dry weight was observed from treatment F0 (Table 5). The dry weight of cabbage varied significantly due to the different levels of NAA after harvest. The treatment 40 ppm NAA dose gave the maximum dry weight (10.5 g) and it was observed in N2 and N3 treatment and minimum dry weight (8.5 g) were observed in N0 treatment (Table 5). The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of the dry weight of purple cabbage (Table 6). The maximum dry weight was observed from F3N2 and the minimum dry weight (8.00 g) was found from the F0N0 treatment. The vegetative growth of this experiment supports the results of Souza et al. (2008), who stated that when organic fertilizer is mixed with inorganic fertilizer used in the soil, it stimulates root growth, which ultimately boosts the dry biomass yield of the kale crop.
3.10. Iron (Fe) content
The Fe content of purple cabbage varied statistically due to the different levels of NPK and vermicompost. A mixture of vermicompost and NPK doses treatment gave the maximum Fe content (1.64 mg) while the control treatment gave the minimum yield (1.29 mg). The maximum Fe content was observed from treatment F3 and the minimum was from the F0 treatment (Table 5). The Fe content of cabbage varied significantly due to the different levels of NAA after harvest. The treatment 40 ppm NAA dose gave the maximum Fe content (1.53 mg) and it was observed in N3 treatment and minimum Fe was observed in N0 treatment (1.39 mg) (Table 5). The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of the Fe content of purple cabbage (Table 6). The maximum Fe content (1.75 mg) was observed in the F3N2 treatment and the minimum Fe (1.25 mg) was found in the F0N0 treatment. The findings of this study agreed with those of Reza et al. (2016).

3.11. Beta carotene content
The Beta carotene content of purple cabbage varied statistically due to the different levels of NPK and vermicompost. A mixture of vermicompost and NPK doses treatment gave the maximum (99.61 µg) Beta carotene while the control treatment gave the minimum yield (17.90 µg) (Table 5). The maximum Beta carotene content was observed from treatment F3 and the minimum was from the F0 treatment. The beta carotene content of cabbage varied significantly due to the different levels of NAA after harvest. 40 ppm NAA dose gave the maximum beta carotene content (72.80 µg) and it was observed in N2 treatment and minimum beta carotene was observed in N0 treatment (34.33 µg) (Table 5). The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of the Beta carotene content of purple cabbage (Table 6). The maximum beta carotene content (142.50 µg) was observed in the F3N2 treatment and the minimum beta carotene (10.10 µg) was found in the F0N0 treatment. The findings of this study agreed with those of Sajib et al. (2016).

4. Conclusions
In conclusion, the values obtained for the growth parameters, yield contributing characters, and biochemical compound of purple cabbage for treatments F3 and N2 were higher than those obtained for the other treatments. Thus, the treatment combination of F3N2 (½ vermicompost and ½ doses of NPK + 40 ppm NAA) provides higher vegetative growth and yields the highest biochemical components.

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Data availability
All relevant data are within the manuscript.

Conflict of interest
None to declare.

Author contributions
MAR designed, carried out the experiments, and wrote the manuscript. JU analyzed the data and supervised the research. ET and MJR were revised and edited in this manuscript. All authors have read and approved the final manuscript.

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