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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: F_0: control, F_1: vermicompost (10 t/ha), F_2: $N_{180kg.ha-1}$; $P_{66kg.ha-1}$ $K_{75kg.ha-1}$ and F_3: ½ vermicompost (5t. ha^{-1}) + $N_{90kg.ha-1}$; $P_{33kg.ha-1}$ $K_{38kg.ha-1}$ 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 Waston, 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 (Muhibbullah *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. In light of the aforementioned elements, the present study aims to find out suitable nutrient sources with optimum doses of NAA for the growth and quality yield of purple cabbage.

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 $23^0$74' N latitude and $90^0$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), Khamarbari, 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: F_0: control, F_1: Vermicompost (10 t/ha), F_2: $N_{180kg.ha-1}$; $P_{66kg.ha-1}$ $K_{75kg.ha-1}$ and F_3: ½ vermicompost (5t. ha^{-1}) + $N_{90kg.ha-1}$; $P_{33kg.ha-1}$ $K_{38kg.ha-1}$ 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 $P \leq .05$. 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 F_3 gave the maximum plant canopy (765.03 cm^2, 1250 cm^2, and 2863.85 cm^2) while the control treatment gave the minimum (608.90 cm^2, 994.05 cm^2, and 2055.88 cm^2) 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 N_2 treatment gave the maximum plant canopy (806.92 cm^2, 1127.38 cm^2, and 2764.69 cm^2) and the minimum plant height (555.08 cm^2, 1086.83 cm^2, and 2308.15 cm^2) were observed in N_0 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 cm^2, 1464.90 cm^2, and 3496.40 cm^2) was observed from F_3N_2 and the minimum plant canopy (502.73 cm^2, 818.13 cm^2, and 1699.13 cm^2) was found from F_0N_0 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
F_0	608.90±28.79b	994.05±47.67b	2055.88±118.73b
F_1	723.28±27.10a	1104.65±26.21ab	2359.33±92.22b
F_2	734.90±42.00a	1223.12±55.70a	2895.13±110.84a
F_3	765.03±35.72a	1250.14±58.72a	2863.85±131.31a
Significance level	**	***	***

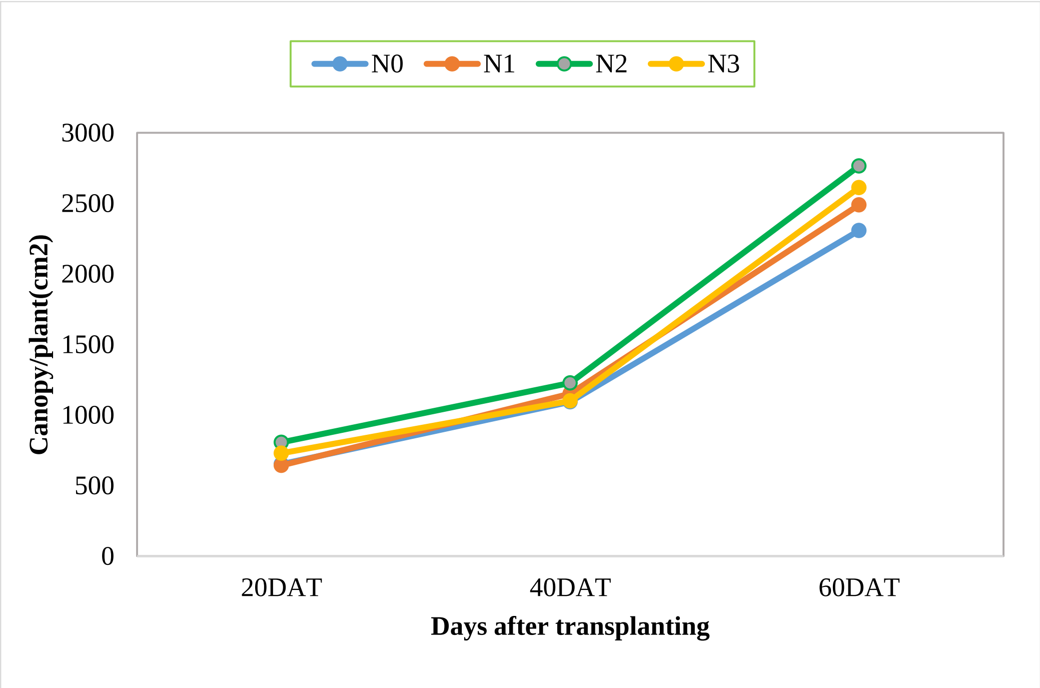

Figure 1. Effect of NAA on plant canopy on different days after transplanting (DAT) of purple cabbage.

Table 2. The combined effect of nutrient sources and NAA on plant canopy of purple cabbage.

Treatment Combination	Canopy/plant (cm^2)		
	20DAT	**40DAT**	**60DAT**
F_0N_0	502.73±33.21e	818.13±34.19d	1699.13±85.53g
F_0N_1	647.47±24.57cde	1095.47±74.37bcd	2340.27±234.29def
F_0N_2	666.13±40.13cde	1066.27±97.76bcd	2154.87±195.33efg
F_0N_3	619.27±82.72cde	996.33±102.56cd	2029.27±316.96fg
F_1N_0	686.07±13.74bcd	1082.67±65.89bcd	2423.07±287.77cf
F_1N_1	687.87±50.31bcd	1170.73±33.05bc	2304.93±24.57dg
F_1N_2	774.53±88.47abc	1058.87±66.78bcd	2198.07±146.47efg
F_1N_3	744.67±52.43bc	1106.33±41.70bcd	2511.27±232.72cf
F_2N_0	751.13±85.95bc	1292.67±176.94abc	2612.93±187.15bf
F_2N_1	564.87±35.82de	1227.20±104.51abc	2744.67±148.98be
F_2N_2	860.47±36.69ab	1319.47±42.39ab	3209.43±252.08ab
F_2N_3	763.13±76.94abc	1053.13±51.98bcd	3013.47±204.95abc
F_3N_0	669.00±49.30cde	1179.80±146.74abc	2497.47±173.64cf
F_3N_1	674.80±17.66cde	1111.27±52.38bcd	2566.00±154.01cf
F_3N_2	926.60±18.40a	1464.90±78.36a	3496.40±31.40a
F_3N_3	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. F_3 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 N_2 treatment and N_0 treatment gave minimum weight (580.30 gm) was observed in N_0 treatment at the different time being of harvest (Table 3). The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of the whole weight of purple cabbage at different harvesting times (Table 4). At harvesting time average maximum cabbage weight (1100.60 gm) was observed from the F_3N_2 treatment and the minimum weight (314.70 gm) was found from the F_0N_0 treatment. 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 weight can be varied statistically due to the different levels of NPK and vermicompost at the different times of harvest. F_3 treatment gave the maximum weight (657.12 gm) while F_0 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 N_2 treatment and minimum weight (369.92 gm) was observed in N_0 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 F_3N_2 the treatment and the minimum weight (159.43 gm) was found from the F_0N_0 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. F_2 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 N_2 treatment and the minimum number (7.92) was observed in N_0 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 F_2N_2 (NPK doses + 40ppm NAA) and the minimum number (4.67) was found from F_0N_0 (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 N_2 treatment and minimum weight (209.58 gm) was observed in N_1 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 F_2N_2 (NPK doses + 40ppm NAA) and the minimum weight (147.63 gm) was found from F_0N_1 (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)
F_0	551.28±44.5b	385.28±44.06b	7.42±0.62b	166.00±17.52c
F_1	630.50±34.7b	436.85±34.05b	8.58±0.67ab	193.65±21.60bc
F_2	825.81±30.66a	556.41±19.61a	9.67±0.31a	269.40±15.53a
F_3	891.32±49.19a	657.12±49.05a	8.58±0.34ab	234.20±14.33ab
Significance level	***	***	**	***
N_0	580.30±57.77b	369.92±44.06b	7.92±0.76	210.38±21.17
N_1	709.75±39.89ab	500.17±27.81a	8.75±0.25	209.58±18.40
N_2	831.41±58.96a	609.26±54.97a	9.00±0.46	222.15±21.01
N_3	777.45±44.03a	556.30±36.54a	8.58±0.60	221.14±23.27
Significance level	***	***	Non-significant	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.

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)
F_0N_0	314.70±14.65f	159.43±43.65a	4.67±0.67	155.27±39.83
F_0N_1	575.63±42.80e	428.00±32.48bc	8.33±0.33	147.63±34.22
F_0N_2	626.13±33.54de	430.07±13.61bc	9.00±0.58	196.07±31.36
F_0N_3	688.67±6.74cde	523.63±50.68bf	7.67±1.45	165.03±48.30
F_1N_0	552.23±122.82e	362.70±79.96b	8.00±2.08	189.53±58.36
F_1N_1	636.57±55.26de	432.67±38.84bc	8.33±0.67	203.90±37.30
F_1N_2	684.62±38.43cde	512.56±78.91be	8.33±1.45	172.07±48.83
F_1N_3	648.57±46.94de	439.47±75.80abc	9.67±1.45	209.10±51.64
F_2N_0	740.60±9.72be	484.66±9.89bcde	9.67±0.33	255.94±19.60
F_2N_1	784.47±11.53bcd	541.90±24.90cf	9.00±0.58	242.57±30.78
F_2N_2	914.30±14.68b	611.37±7.04ef	10.33±0.67	302.93±12.46
F_2N_3	863.87±105.45bc	587.71±54.86cf	9.67±0.88	276.16±52.74
F_3N_0	713.67±24.85cde	472.90±15.50be	9.33±0.33	240.77±35.28
F_3N_1	842.33±82.07bc	598.10±57.34def	9.33±0.33	244.23±29.32
F_3N_2	1100.60±46.52a	883.07±42.32g	8.33±0.67	217.53±36.37
F_3N_3	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 (F_3) treatment gave the maximum length (9.95 cm) while the control (F_0) 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 N_2 treatment and the minimum length (7.31 cm) was observed in N_0 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 F_3N_2 and the minimum head length (3.43 cm) was found from the F_0N_0 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 (F_3) treatment gave the maximum breadth (10.56 cm) while the control (F_0) 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 N_2 treatment and the lowest breadth (8.77 cm) was observed in N_0 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 F_3N_2 treatment and the shorter head breadth (6.68 cm) was found in the F_0N_0 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
F_0	4.73±0.47c	7.39±0.56c	8.50±0.26c	1.29±0.01d	17.90±1.82c
F_1	8.48±0.54b	8.69±0.56b	11.50±0.26a	1.38±0.02c	38.43±3.57b
F_2	9.87±0.06a	10.36±0.20a	9.50±0.50ab	1.55±0.02b	52.38±3.21b
F_3	9.95±0.15a	10.56±0.21a	10.00±0.43b	1.64±0.04a	99.61±12.66a
Significance level	***	***	***	***	***
N_0	7.31±0.86	8.77±0.64	9.00±0.30	1.29±0.01d	17.90±1.82c
N_1	8.07±0.79	9.12±0.51	9.50±0.50	1.38±0.02c	38.43±3.57b
N_2	8.87±0.54	10.12±0.41	10.50±0.50	1.55±0.02b	52.38±3.21b
N_3	8.78±0.61	8.99±0.62	10.50±0.50	1.64±0.04a	99.61±12.66a
Significance level	Non-significant	Non-significant	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
F_0N_0	3.43±0.03c	6.68±0.48	8.00±0.00	14.64±1.82g	1.25±0.03g	10.10±0.00
F_0N_1	3.63±0.30c	7.20±0.35	8.00±0.00	17.83±1.35ef	1.29±0.007g	14.00±0.00
F_0N_2	6.13±0.29b	8.93±1.22	10.00±0.00	17.92±0.57ef	1.30±0.01fg	23.20±0.00
F_0N_3	5.73±1.29b	6.75±1.85	8.00±0.00	21.82±2.11bf	1.32±0.01efg	24.30±0.00
F_1N_0	6.48±1.66b	7.88±2.33	10.00±0.00	15.11±3.33f	1.32±0.01efg	23.30±0.00
F_1N_1	8.92±0.49a	8.99±0.76	12.00±0.00	18.03±1.62ef	1.36±0.03efg	32.40±0.00
F_1N_2	8.83±0.70a	9.38±0.30	12.00±0.00	21.36±3.29cf	1.39±0.05dg	55.00±0.00
F_1N_3	9.67±0.15a	8.50±0.42	12.00±0.00	18.31±3.16def	1.44±0.00cf	43.00±0.00
F_2N_0	9.63±0.07a	9.87±0.22	10.00±0.00	20.19±0.41cf	1.46±0.02cde	48.60±0.00
F_2N_1	10.02±0.11a	10.44±0.44	8.00±0.00	22.58±1.04be	1.51±0.05bcd	47.00±0.00
F_2N_2	9.94±0.07a	10.87±0.49	8.00±0.00	25.47±0.29bc	1.58±0.04bc	70.50±0.00
F_2N_3	9.90±0.12a	10.27±0.33	12.00±0.00	24.49±2.29be	1.63±0.01ab	43.40±0.00
F_3N_0	9.71±0.18a	10.13±0.54	8.00±0.00	19.70±0.64cf	1.54±0.10bc	55.30±0.00
F_3N_1	9.74±0.07a	10.38±0.45	10.00±0.00	24.92±2.39bcd	1.55±0.11bc	60.00±0.00
F_3N_2	10.57±0.03a	11.29±0.05	12.00±0.00	36.80±1.77a	1.75±0.00a	142.50±0.00
F_3N_3	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	Non-significant	***	***	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 F_3. 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 N_2 treatment and the minimum yield was observed in N_0 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 F_3N_2 and the minimum yield/ha (14.64 ton) was found from the F_0N_0 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).

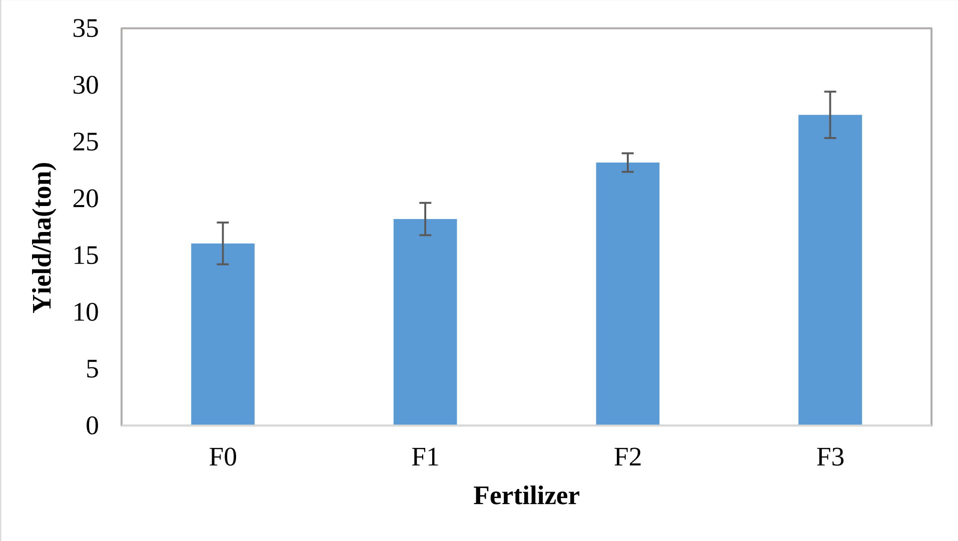

Figure 2. Effect of fertilizer on yield/ha of purple cabbage at harvest time.

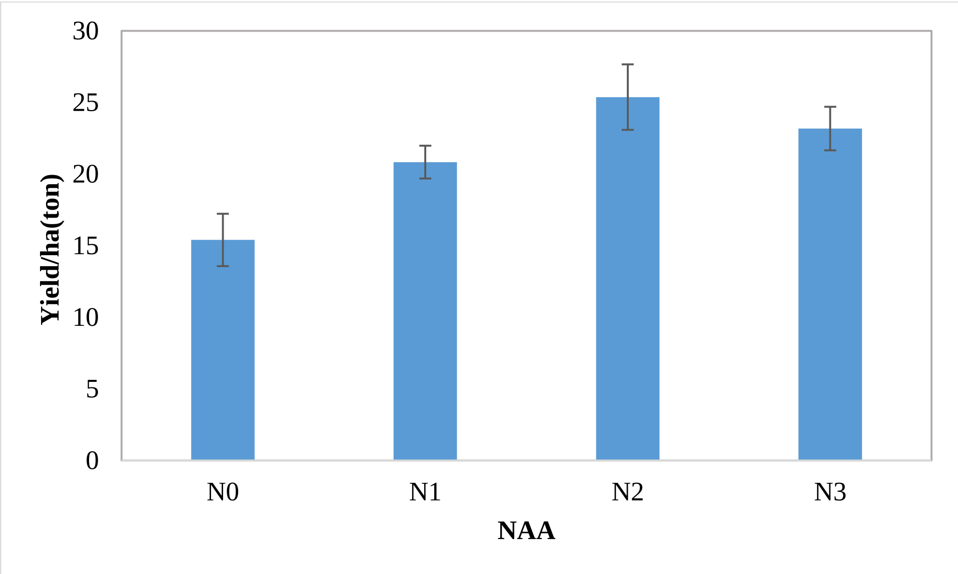

Figure 3. Effect of NAA on yield/ha of purple cabbage at harvest time.

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 F_1 and the minimum dry weight was observed from treatment F_0 (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 N_2 and N_3 treatment and minimum dry weight (8.5 g) were observed in N_0 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 F_3N_2 and the minimum dry weight (8.00 g) was found from the F_0N_0 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 F_3 and the minimum was from the F_0 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 N_3 treatment and minimum Fe was observed in N_0 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 F_3N_2 treatment and the minimum Fe (1.25 mg) was found in the F_0N_0 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 F_3 and the minimum was from the F_0 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 N_2 treatment and minimum beta carotene was observed in N_0 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 F_3N_2 treatment and the minimum beta carotene (10.10 µg) was found in the F_0N_0 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 F_3N_2 ((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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