GROWTH AND YIELD OF PURPLE CABBAGE INFLUENCED BY NUTRIENT SOURCES AND NAA

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BY

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CERTIFICATE

*This is to certify that the thesis entitled, "**GROWTH AND YIELD OF PURPLE CABBAGE INFLUENCED BY NUTRIENT SOURCES AND NAA**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN HORTICULTURE** embodies the result of a piece of bona fide research work carried out by **MAHMUDA AKTER RICKTA; Registration No. 13-05259** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

I further certify that any help or sources of information, as has been availed of during the course of this investigation have been duly acknowledged.

Dated: June, 2020
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Dedicated to
My Beloved parents

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ABSTRACT

The experiment was conducted at Horticultural Farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2018 to February 2019 to study the application of nutrient sources interaction with NAA (Naphthalene acetic acid) for investigating the growth and yield of purple cabbage. The experiment was consisted of two factors. Factor A: nutrient sources; vermicompost, and NPK doses. Factor B: four levels of NAA; N_0: 0 ppm, N_1: 20 ppm, N_2: 40 ppm and N_3: 80 ppm were used for the present study. The experiment was carried out in RCBD with three replications. From the study, 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 N_2 (40 ppm) treatment and the lowest yield (15.41 t/ha) was found from N_0 (control) treatment. In the case of combined effect, the highest yield of purple cabbage (36.80 t/ha) was obtained from F_3N_2 (½ vermicompost and ½ NPK doses + 40 ppm NAA) treatment combination and the lowest yield (14.64 t/ha) was found from F_0N_0 (control) treatment combination. Combine mixture of vermicompost, NPK doses, and NAA appeared to be the best for the cultivation of purple cabbage under the Sher-e-Bangla Agricultural University Farm condition.

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LIST OF ABBREVIATIONS

BARI	=	Bangladesh Agricultural Research Institute
cm	=	Centimeter
^{0}C	=	Degree Centigrade
DAT	=	Days after transplanting
et al.	=	and others *(at elli)*
Kg	=	Kilogram
Kg/ha	=	Kilogram/hectare
g	=	gram (s)
LSD	=	Least Significant Difference
MP	=	Muriate of Potash
m	=	Meter
P^H	=	Hydrogen ion conc.
RCBD	=	Randomized Complete Block Design
TSP	=	Triple Super Phosphate
t/ha	=	ton/hectare
%	=	Percent
NAA	=	Naphthalene acetic acid

CHAPTER-I

INTRODUCTION

Purple Cabbage (*Brassica oleracea* var. *Capitata* L.) belongs to the family Brassicaceae is one of the important vegetable cole crops in temperate, subtropical, and tropical regions and grown throughout the country. It is a herbaceous, biennial, dicotyledonous plant distinguished by a short stem upon which a crowded mass of leaves, usually green but in some varieties red or purple, however when it is in an immature form, compact and globular cluster characteristics in cabbage head develops (Anon. 2011).

The edible portion of the cabbage plant is the head which is formed by the fleshy leaves overlapping one another. It has been reported that 100 g of the green edible portion of cabbage contains 92% water, 24 kilocalories of food energy, protein (1.5g), carbohydrate (4.8g), calcium (40mg), iron (0.6mg).

Purple cabbage consumption is increasing significant in recent years, characterized by exceptional health-enhancing properties and many beneficial sensory characteristics (Wojciechowska *et al*., 2007). Chemical compounds found in purple cabbage resist DNA oxidative damage and are also involved in the inhibition of angiogenesis (Bast and Haenen, 2002). These processes help the regulation of neoplasm diseases, while inhibition of angiogenesis alone contributes to a reduction in the growth of tumors (Hagivara *et al*., 2002). Purple cabbage substances have a beneficial effect on the excretion of insulin in pancreas cells and also have anti-inflammatory properties (McDougall *et al*., 2007). Active antioxidants found in purple cabbage leaves. Purple cabbage is generally distinguished by the strongest antioxidant properties of vegetables, much stronger than those with spinach, broccoli, onion, or tomato (Proteggente *et al*., 2002). The amount of biologically active compounds in plants depends on their genotype and conditions of cultivation, as well as the environment.

The productivity of cabbage is likely to decrease in different types of soils due to the continuous use of high analysis chemical and imbalanced fertilizers and less addition of plant growth regulators. They are separate applications though

foliage would definitely enhance the crop productivity as well as soil fertility on a sustainable basis. The higher yield of cabbage is related to the judicious application of fertilizer and proper cultural management etc. If a plant is supplied with the optimum amount of nitrogen, there is a tendency to increase leaf cell number and cell size with an overall increase in leaf production (Morton and Waston, 1948).

Growing any crop depends on many factors one of which is the source of nutrients. The yield and the quality of cabbage are connected to the judicious application of manure and fertilizer. Via two sources, viz, nutrients can be applied, inorganic, and organic. Increased use of inorganic fertilizer poses risks to health and emissions to the atmosphere. Organic nutrient sources are less harmful to the ecosystem and are pleasant. The use of renewable sources of nutrients should be promoted to reduce the economic return, preventing health risks and sustainable agriculture. A judicious mix of organic and inorganic nutrients, on the other hand, might help to achieve a good economic return, leaving the soil state congenial to the soil.

Cabbage has been found to show quick growth when treated with plant growth regulators. Among the growth regulators auxin such as NAA (Naphthalene acetic acid) causes enlargement of the plant cell. Application of NAA stimulates morphological characters like plant height, the number of leaves, head diameter, the thickness of the head as well as the weight of the head. Therefore, it was thought that it is necessary to find out the effective dose of NAA in promoting growth and yield components of purple cabbage.

Considering the above factors, the following objectives are given below-

- To determine the influence of various organic and inorganic nutrient sources on the growth and yield of purple cabbage.
- To find out the optimum level of NAA on the growth and yield of purple cabbage.
- To determine the combined effect of nutrient sources and NAA on the growth and yield of purple cabbage.

CHAPTER-II

REVIEW OF LITERATURE

Purple Cabbage is an important crop of vegetables in many countries around the world. Recently considerable interest has been established in the gain of the use of NAA and various nutrient sources, which has been known to play a crucial role in growing purple cabbage growth and yield. A great deal of research has been published on the use of NAA and nutrient sources such as N, P, K, and vermicompost in various vegetables, including purple cabbage, and the results already obtained are of exceptional importance. In various parts of the world, a good number of studies have been carried out on the influence of nitrogen, phosphorous, potassium, and vermicompost on the growth and yield of purple cabbage. However, in Bangladesh, a small number of studies are found in this regard. However, some of the research findings have been discussed in this chapter regarding the effects of different levels of NAA and nutrient sources on the growth and yield of purple cabbage.

2.1. Effect of NAA on the growth and yield of cabbage

Singh (2015) experimented with Gwalior during the Rabi season of 2012-13 to study the effect of a mixture of GA_3 and NAA with four concentrations i.e. 0, 10, 15, and 20 ppm on growth, yield attributes, and the yield on cabbage varieties, namely Krishna (Hybrid), Kranti (Hybrid), Golden acre and Pride of India. Results revealed that 15 ppm GA_3 + NAA was found the most effective growth regulator in increasing the growth, yield attributes, and head yield (688.50 q/ha).

Chaurasiya *et al*. (2014) experimented to study the response of cabbage cv. Pride of India to foliar application of PGRs namely GA_3 and NAA with different concentrations. The treatments comprised three levels of each PGRs namely GA_3 (30, 60, 90 ppm) and NAA (40, 80, 120 ppm) along with control. Foliar spray of GA_3 and NAA was given at 30 and 45 DAT of cabbage. Looking to the results, it may be concluded that foliar application GA_3 60 ppm or NAA 80 ppm can be

recommended to cabbage growers for obtaining better growth and yield of cabbage.

Thapa *et al*. (2013) experimented to determine the effect of GA_3, NAA, and their combinations (applied as seedling dipping) on growth, yield, and quality improvement of sprouting broccoli. GA_3 30 mg/l+ NAA 30 mg/l treatment (T10) showed the best result concerning head weight, head diameter, plant height, plant spread, projected yield, number of sprouts/plant, and sprout weight, whereas maximum ascorbic content has been estimated with T9– GA_3 20 mg/l+ NAA 20 mg/l.

Lendve *et al.* (2010) experiment to study the response of cabbage cv. Pride of India to foliar application of GA_3 and NAA with different concentrations. It was found that GA_3 60 ppm significantly increased the plant height, number of leaves, plant spread, stem diameter, plant weight, head weight, head diameter as well as head yield than the other treatments and control.

Saravaiya *et al.* (2010) experimented on the influence of the foliar application of GA_3 and NAA on growth, yield, and quality of cabbage (*Brassica oleracea* var. *capitata* cv. Golden Acre) to assess the response of cabbage to foliar application of PGRs namely, GA_3 and NAA with different concentrations. Total eight treatments comprised of three concentrations of each PGRs namely, GA_3 (5, 10, and 15 mg/l) as well as NAA (25, 50, and 75 mg/l) along with distilled water spray and absolute control. The maximum head yield of 29.39 t/ha was noticed in the treatment of the foliar application of GA_3 5 mg/l.

Soni (2007) reported that among the concentrations of plant growth regulators mixture, the application of 20 ppm of GA_3 + NAA produced the significantly higher fruit yield up to 433 q/ha as well as the highest yield components of tomato varieties. The net return was highest up to Rs. 104829 along with the highest benefit-cost ratio (5:28). The variety Pusa Early Dwarf with 20 ppm of GA_3 + NAA mixture produced the highest yield (552 q/ha) as compared to all other combinations, the net return is up to Rs. 142461/ha with the highest B: C ratio up to 7:19.

Khamparia and Tiwari (2006) conducted a field experiment to evaluate the best growth regulator on yield and quality of onion. NAA (30 ppm) applied through the solution soaking method for eight hours gave the maximum yield (335.4 q/ha) and net return (Rs. 46,702/ha). NAA gave the lowest carbohydrate content and the highest pyruvic acid and sulfur content as well as storage qualities of onion bulb, however, the reverse was true in the case of control treatment.

Mishra (2006) concluded from the study that Krishna and then Kranti hybrid varieties of cabbage performed the best in comparison to Golden Acre and Pride of India. The mixture of GA_3 + NAA growth substances played an important role in increasing the growth, yield net income, and quality of cabbage varieties. Krishna treated with 15 ppm GA_3 + NAA concentration brought about the highest production (688.50 q/ha).

Kar *et al*. (2003) experimented on the effect of variety and growth regulators on the growth and yield of cabbage (*Brassica oleracea* var. *capitata*) during October 2002 March 2003. The highest gross and marketable yield of cabbage were obtained from the plants sprayed with 50 ppm NAA.

Gupta *et al.* (2001) reported that the maximum plant height of tomato at 75 DAT was 82 cm and a minimum number of branches 30 to 60 DAT significantly different with 75 ppm NAA along with 2000 ppm NAA and Humor (P_3M_2) as 28 days as compared to control. Minimum days for fruit setting in the tomato plant was 42 DAT observed significantly with the treatment of 25 ppm NAA along with Humor (P_3M_2).

Vijoy and Kumar (2000) reported that 30-day old Cauliflower (cv. Pant Subhra) seedlings were transplanted into experimental plots and treated with 50 or 100ppm GA_3, 5 or 10ppm IBA, or 100 or 2000ppm NAA at 15 and 30 days of growth. The results clearly revealed that GA_3 produced the tallest plants, the largest curds, and the highest curd yields.

Yadav *et al.* (2000) experimented on the effects of NAA at 50, 100, and 150 ppm, GA_3 at 50, 100, and 150 ppm, and succinic acid at 250, 500, and 750 ppm, applied at 2 spraying levels (1 or 2 sprays at 30 and 60 days after transplanting), on growth and yield of cabbage cv. Golden Acre. The maximum plant height

(28.4 cm) and plant spread (0.187 m^2) resulted from 2 sprays with GA_3 at 150 ppm. The highest number of open leaves (23.6) and yield (494.78 q/ha) was obtained in the treatment with 2 sprays of GA_3 at 100 ppm.

Dharmender *et al*. (1996) experimented with growth regulators and found that GA_3 and NAA (both at 25, 50, or 75 ppm) enhanced the yield of cabbage (cv. Pride of India). The higher yield was observed with the following treatment as 50p pm GA_3 followed by 50 ppm NAA. Combinations and a higher concentration of plant growth regulators proved less effective and were uneconomic in comparison to the control.

Islam *et al.* (1993) investigated to determine the effective concentration of NAA and GA_3 for promoting growth, yield, and ascorbic acid content of cabbage. They used 12.5, 25, 50, and 100 ppm both the NAA and GA_3 and applied at three different methods i.e. seedling soaked for 12 hours, spraying at 15 and 30 days after transplanting. They found that ascorbic acid content increased up to 50 ppm when sprayed twice with both the growth regulators, while its content was declined afterward. They also added that two sprays with 50 ppm GA_3 were suitable both for higher yield and ascorbic acid content of cabbage.

Patil *et al*. (1987) experimented with a field trial with the cabbage cultivar Pride of India by applying GA_3 and NAA each at 25, 50, 75, and 100 ppm one month after transplanting. Both the GA3 and NAA increased plant height significantly. The maximum plant height and head diameter and head weight were noticed with GA_3 at 50ppm followed by NAA at 50 ppm. A significant number of outer and inner leaves were noticed with both GA_3 and NAA. The maximum number of leaves and maximum yield (23.83 t/ha) was obtained with 50 ppm GA_3.

Kato and Sooen (1980) observed that leaf petiole epinasty in cabbage appeared to be controlled by the hormone balance at the epical region of the stem. They also reported that applied NAA induced a downward movement of the wrapper leaves of decapitated plants and the plants with the entire heads and in the leaves of young seedlings but GA_3 induced the upward movement of leaves.

2.2. Effect of vermicompost

Ahmed *et al.* (2017) were carried out a study during two successive winter seasons of 2014/2015 and 2015/2016 under green roof system condition at the Central Laboratory for Agricultural Climate, Agricultural Research Center, Egypt with aimed to optimize the use of local substrates (sand and rice husk) and provide a vermicomposting technique for recycling the urban organic wastes through investigating different vermicompost rates (10, 20 and 30%) as a substrate amendment mixed with sand: rice husk (1:1V/V) compared to peat moss: perlite (1:1V/V) (control) combined with three different volume of pots (4, 6, and 8 L) on vegetative growth, yield and quality of celery and red cabbage. The obtained results indicated that increasing pot volume from 4 to 8 L of substrate led to an increase in the vegetative and yield of red cabbage in reverse to the economic efficiency. The medium pot volume of the substrate gave the highest economic yield of red cabbage compared to the other volumes. Increasing the rate of vermicompost from 10 to 20% led to an increase in the vegetative and yield characteristics of red cabbage while increasing up to 30% had a negative impact.

An experiment was conducted by Ismail *et al.* (2017) to investigate the effect of vermicompost application in red cabbage cultivation under field conditions. The treatments included in the study were: U-0 (control), U-1 (0 kg da^{-1} vermicompost + N: P: K), U-2 (100 kg da-1 vermicompost + N: P: K), U-3 (200 kg da^{-1} vermicompost + N: P: K), U-4 (400 kg da-1 vermicompost + N: P: K) and U-5 (800 kg da^{-1} vermicompost + N: P: K). The results indicated that quality parameters, mineral nutrient status, and yield were positively affected by vermicompost applied in increasing doses. Vermicompost applications appeared to be effective in achieving sufficient levels in foliar N, P, Fe, Zn, and Mn contents, and the yield of red cabbage was found to be 52.65% higher than the control. Based on these results and economic factors, it was concluded that, in addition to mineral fertilizers, application of vermicompost in the rate of 400 kg da^{-1} may be recommended for red cabbage cultivation.

The field experiment was conducted by Alam *et al.* (2017) at On-Farm Research Division, Bangladesh Agricultural Research Institute (BARI), Rangpur, Bangladesh during the Rabi season of 2014-15, and 2015-16 to evaluate the effects of vermicompost on the growth and yield of cabbage. The experiment was laid out with seven treatments viz; T_1=100% recommended chemical fertilizer (RCF), T_2=80% RCF, T_3 = 60% RCF, T_4 = 100% RCF+ Vermicompost (VC) @ 1.5 t ha-1, T_5 = 80% RCF+ VC @ 3 t ha-1, T_6 = 60% RCF+ VC @ 6 t ha-1 and T_7 = Absolute control. The highest head yield was recorded from T_4 during 2014-15 and 2015-16 (59.21 t ha-1 and 72.61 t ha-1, respectively) where the lowest yield was obtained from T_7 (27.11 t ha-1 and 24.05 t ha-1, respectively). The highest gross margin was calculated in T_4 (203,060 and 270,060 Tk. ha-1 in 2014-15 and 2015-16, respectively) and the lowest was in T_7 (74,300 and 59,000 Tk. ha-1 in 2014-15 and 2015-16, respectively).

A pot experiment was conducted by Nurhidayati *et al*. (2016) to assess the effect of three kinds of vermicompost materials and P. corethrurus population on plant yield and quality of cabbage under organic growing media compared with inorganic treatment. The first factor is the kind of vermicompost material which consists of three levels (the mixture of mushrooms media waste, cow manure, and vegetable wastes (V_1), mushrooms media waste, cow manure and leaf litter (V_2), mushrooms media waste, cow manure, vegetable wastes and leaf litter (V_3). The results showed that the application of various vermicompost had significantly higher yields than the inorganic treatment. Vermicompost V_1 and V_2 gave the highest yield. The results suggest that the application of vermicompost can increase the yield and quality of cabbage.

Reza *et al*. (2016) experimented to investigate nutrient uptake, growth, and yield of the cabbage (*Brassica oleracea* var. capitata) variety 'Atlas70'as influenced by the application of different organic fertilizers. Treatments were T_1= Soil Test Based 100% Recommended Dose of Chemical Fertilizer (RDCF), T_2= 5 t/ha Cow dung (CD) + integrated plant nutrient system (IPNS) based Chemical fertilizers (CF), T_3=5 t/ha Poultry Manure (PM) + integrated plant nutrient system (IPNS) based Chemical fertilizers (CF), T_4= 5 t/ha vermicompost (VC)

+ integrated plant nutrient system (IPNS) based Chemical fertilizers (CF), T_5= Absolute control. Results of the experiment showed that the same amount of N, P, K, and S from cow dung, poultry manure, and vermicompost showed significant differences in plant height, unfolded leaves, head circumference, marketable yield, total yield, and nutrient content in cabbage.

An investigation was made by Sajib *et al*. (2015) on the yield performance of cabbage under different combinations of manures and fertilizers at Hogladanga village under Botiaghata Upazila, Khulna. The treatments were T_1 recommended doses of NPK (urea @ 350 kg ha-1, TSP @ 250 kg ha-1, MoP @ 300 kg ha-1, respectively), T_2 = cow dung @ 10 t ha-1, T_3 = vermicompost @ 10 t ha-1, T_4 =Trichoderma compost @ 10 t ha-1, T_5 = 50% cow dung + 50% recommended doses of fertilizer, T_6 = 50% vermicompost + 50% recommended doses of fertilizer and T_7 = 50% Trichoderma compost + 50% recommended doses of fertilizer. The growth and physio-morphological characteristics, yield attributes, and yield were positively and significantly influenced by the application of vermicompost with a recommended dose of NPK and also cow dung compost with the recommended dose of NPK. In most cases, 50% vermicompost + 50% recommended doses of fertilizer receiving treatment performed better. However, the maximum yield of cabbage (57.16 t ha-1) was obtained from the treatment receiving 50% vermicompost + 50% recommended doses of fertilizers, and the lowest yield of cabbage (38.48 t ha-1) was obtained from the control. But considering the highest benefit-cost ratio of cabbage (3.63) was noted when applied 50% cow dung + 50% recommended doses of fertilizer were applied for sustainable crop production.

An experiment conducted by Pour *et al*. (2013) to evaluate the possible effects of different concentrations of vermicompost on the growth and physiology of cabbage seedling. Vermicompost were used at five different levels (0, 10%, 20%, 40% and 80%). The seeds were planted in five different prepared soil mixtures with vermicompost and grouped in five different treatment groups including control (C), vermicompost of 10% (V_{10}), vermicompost of 20% (V_{20}), vermicompost of 40% (V_{40}), and vermicompost of 80% (V_{80}). Findings revealed

that the applied vermicompost affected the leaf characteristics i.e. number of produced leaves, leaf area, fresh and dry mass. These findings indicated that the effects of vermicompost on plant growth and development not only were nutritional but also hormonal and biochemical and the utilization of high levels of vermicompost, especially at the seedling stage, neither is not only economic but also may have adverse effects on the plant growth and development.

Chatterjee *et al.* (2013) conducted a field experiment at UBKV, Pundi bari, West Bengal, India to access the influence of different organic amendments on growth, head yield, and nitrogen use efficiency in cabbage. The experiment comprised of 15 different nutrients source combining inorganic fertilizers, organic manures (farmyard manure and vermicompost), and Azophos biofertilizers. Growth and head attributes of cabbage were significantly influenced by different nutrient combinations and vermicompost emerged as a better organic nutrient source over farmyard manure. The nutrient schedule comprising of a higher amount of vermicompost (5 t/ha) along with 75% of recommended inorganic fertilizers in presence of biofertilizer inoculation emerged as a potential nutrient source and resulted in many fold improvement in the form of vigorous growth, advanced head maturity, maximum curding percent and highest head yield as compared other nutrient combination.

Getnet and Raja (2013) experimented to produce vermicompost from organic solid wastes by using red earthworm, Eisenia fetida, and to check growth-promoting and pest suppression properties on cabbage, *Brassica oleracea.* Vermicompost was applied at the rate of 25, 50, 100, and 200gm/plant individually. For each application 10 plants were selected and vermicompost application was continued on a bimonthly basis. A total number of leaves per plant; leaf length and width; plant stands height and root length; cabbage head round distance and weight were the parameters studied. The number of plants stands height, cabbage head, leaves of cabbage were also significantly different in experimental cabbage compared to control. In conclusion, vermicompost has a significant impact on cabbage growth promotion.

Rai *et al.* (2013) experimented to assess the effect of vermicompost, integrated with different rates of recommended doses of NPK for growth, yield, and quality of cabbage. The investigation was laid out in RCBD with ten treatments viz., T_1: 100% NPK (RR), T_2: 75% NPK (RR) + VC 3 t/ha, T_3 :75% NPK (RR) + VC 2 t/ha, T_4: 75% NPK (RR) + VC 1 t/ha, T_5: 75% NPK (RR), T_6: 50% NPK (RR) + VC 3 t/ha, T_7: 50% NPK (RR) + VC 2 t/ha, T_8: 50% NPK (RR) + VC 1 t/ha, T_9: 50% NPK (RR) and T_{10}: VC 5 t/ha. The results revealed that combined use of vermicompost and the recommended dose of NPK were statistically significant towards the growth and yield of cabbage. The combined use of the recommended dose of 75% NPK (RR) +VC 3 ton/ha, had recorded the maximum gross weight of the plant and net weight of the head. Application of vermicompost along with inorganic fertilizers reduced the days taken to maturity. It was concluded that the application of vermicompost in combination with inorganic NPK fertilizers increased the productivity of cabbage.

Ghuge *et al.* (2007) conducted a field experiment in Parbhani, Maharashtra, India to assess the effect of combined use of organic and inorganic nutrients sources on the growth and yield of cabbage. The experiment consisted of 10 treatments. Among the treatments, 50% RDF + 50% vermicompost gave the maximum plant spread, head circumference, and head weight and total marketable yield of cabbage.

An experiment was conducted by Zhenyu and Yongliang (2005) to test the efficiency of vermicompost, and two crops were produced. The results showed that employing vermicompost could increase available nutrients, promote the growth of leaf area, accelerate the accumulation of dry matter, when the first and second crops were finished, compared to the treatment of no fertilizer, only applying vermicompost increased the yield of cabbage by 45.5% and 77.5%, applying vermicompost with inorganic fertilizer increased yield by 76.1% and 103.9%, the differences great significant.

Chaudhary *et al*. (2003) conducted a field experiment in Orissa, India to investigate the use of vermicompost in cabbage cv. S-22 and tomato cv. Golden Acre production. Vermicompost was prepared using Gliricidia leaves and

Eisenia fetida and was applied at 100 and 200 g/plant with or without farmyard manure (FYM), at 250 and 500 g/plant. The treatment received VC at 200 g/plant + FYM at 250 g/plant was the best for obtaining sustainable yields in cabbage by ensuring proper growth and development.

CHAPTER-III

MATERIALS AND METHOD

This chapter embodies a concise dissertation of the method adopted and materials used during the course of the experiment. It includes a short description of the location of the experimental site, soil, and climate condition of the experimental plot, design of the experiment, data collection procedure, and data analysis.

3.1 Experimental site

3.1.a Experimental period

The field experiment was conducted from September 2018 to February 2019.

3.1.b Experimental location

The present study was conducted in the Horticultural Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207. 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 (Appendix I).

3.2 Soil characteristics

The soil of the experimental field belongs to the Tejgaon series under the Agro-ecological Zone, Madhupur Tract (AEZ-28), and the General Soil Type is Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the study. The collected soil was air-dried, grind, and passed through a 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka for some important physical and chemical properties. The soil was having a texture of sandy loam with pH and organic matter capacity 5.9 and 0.78%, respectively, and the soil composed of 28% sand, 42% silt, 30% clay. Details descriptions have been presented in Appendix III.

3.3 The climatic condition of the experimental site

The experimental area is situated in the sub-tropical climate zone, which is characterized by heavy rainfall from April to September and scanty rainfall during the rest of the year. The monthly average temperature, humidity, rainfall, and sunshine hour during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix II. During the experimental period, the maximum temperature (30.42^0C) was recorded in October 2018, whereas the minimum temperature was (11.70^0C) in January 2019. The highest humidity (78%) was recorded in October 2018, while the highest rainfall (30 mm) in February 2019, and the highest sunshine hour (6.9 hours) in October 2018.

3.4 Experimental details

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

Treatments of the experiment

The experiment consists of two factors:

Factor A-Different nutrient sources-

i. F_0 : control
ii. F_1 : Vermicompost (10 t/ha)
iii. F_2 : N(180kg/ha); P (66kg/ha); K (75kg/ha)
iv. F_3 : ½ vermicompost and ½ NPK doses

Factor B-Different levels of NAA

i. N_0 : 0 ppm
ii. N_1 : 20 ppm
iii. N_2 : 40ppm
iv. N_3 : 80 ppm

Treatment combinations: F_0N_0, F_0N_1, F_0N_2, F_0N_3, F_1N_0, F_1N_1, F_1N_2, F_1N_3, F_2N_0, F_2N_1, F_2N_2, F_2N_3, F_3N_0, F_3N_1, F_3N_2, F_3N_3.

Table 1: **Details of the experiment**-

Design	Randomized Complete Block Design (RCBD
Number of treatments	16
Number of replications	3
Total number of plots	48
Net area of plot	2.4m×1.2m
Plant to plant distance	60cm
Row to row distance	40cm
Distance between plots	50cm
Distance between blocks	50cm
Crop	Purple cabbage
Variety	Ruby king
Sowing of seed in seedbed	18 October, 2018
Transplanting date	15 November, 2019

The plan of layout is illustrated in figure 1 below-

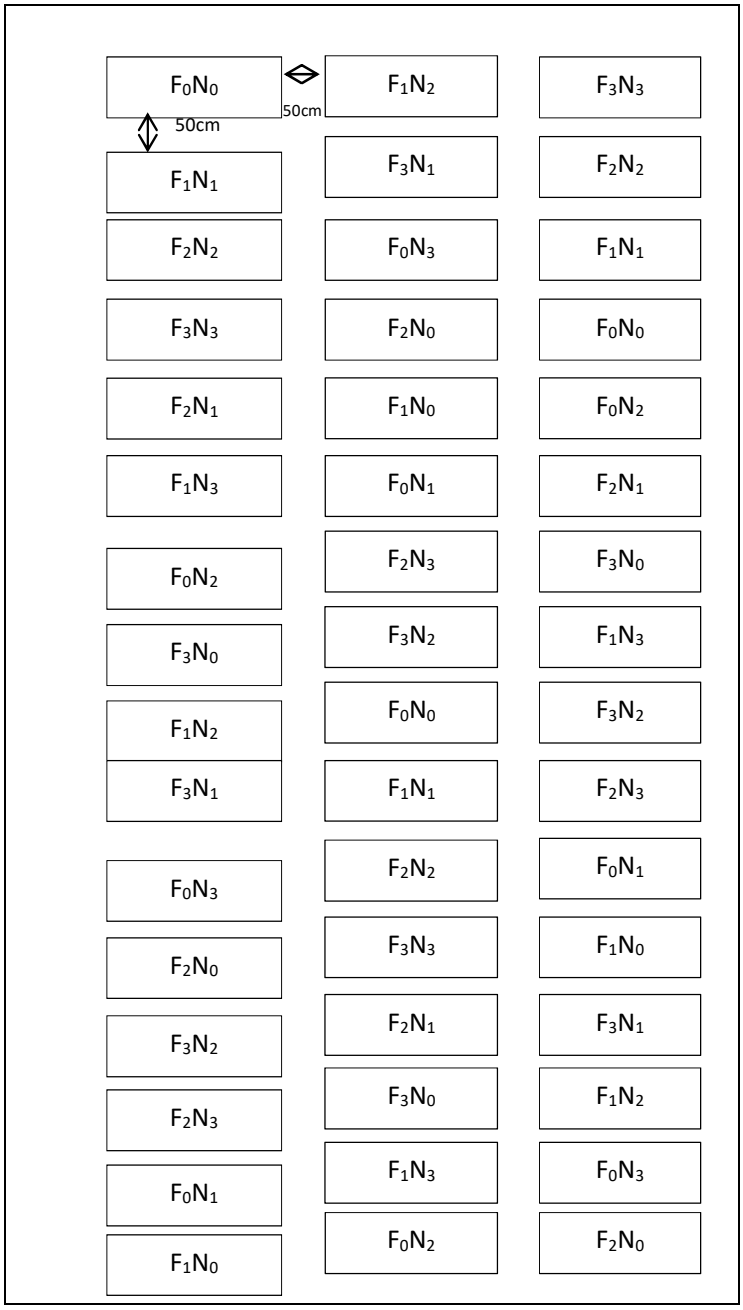


Figure: A layout of the experimental field

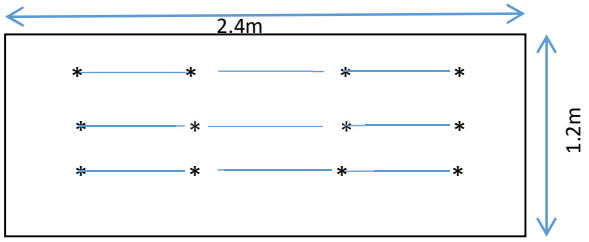
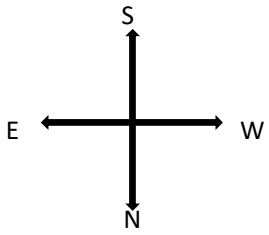


Figure: Layout of a unit plot



Legend:
Plot size: 2.4mx1.2m
Plant-plant distance: 60cm
Row-row distance: 40 cm
Block-block distance: 50cm
Plot-plot distance: 50cm

Factor A: Nutrients sources
F_0: Control
F_1: Vermicompost
F_2: Recommended doses of NPK
F_3: 1/2 vermicompost and 1/2 doses of NPK

Factor B: Levels of NAA
N_0: 0 ppm
N_1: 20 ppm
N_2: 40 ppm
N_3: 80 ppm

3.5 Preparation of NAA solution

For preparing the solution of NAA 20, 40, and 80 ppm, separate weighing was taken for each concentration by electrical balance and then after that they were put in separate test-tube. The 99.99% pure ethyl alcohol was taken and added to the test-tube to dissolve NAA. Dissolve 25 mg in 1 ml KOH (1N), then complete the volume to 25 ml by boiling distilled water. Keep the solution (stock) in the refrigerator. Add 1 ml of the previous solution (before autoclaving) to 1 L MS medium to prepare 1 L MS basal medium containing 1 mg/L NAA.

3.6 Growing of crops

3.6.a Raising of seedlings

The seedlings of purple cabbage were raised at the Horticultural Farm, SAU, Dhaka in a 3 m × 1 m size seedbed. The soil of the seedbed was well plowed and prepared into loose friable dried masses and to obtain good tilth. Weeds, stubbles, and dead roots of any previous crop were removed. To control damping-off disease culprit fungicide was applied. Ten (10) grams of seeds were sown in each seedbed on October 18, 2018. After sowing, the seeds were covered with finished light soil. At the end of germination, shading was done by bamboo mat (chatai) over the seedbed to protect the young seedlings from scorching sunshine and heavy rainfall. Light watering, weeding done as and when necessary to provide seedlings with an ideal condition for better growth.

3.6.b Preparation of the main field

The selected plots of the experiment were opened on the 5th of September 2018 with a power tiller and left exposed to the sun for a week. Subsequently, cross plowing was done five times with a country plow followed by laddering to make the land suitable for transplanting the seedlings. All weeds, stubbles, and residues were eliminated from the field. Finally, a good tilth was achieved.

3.6.c Transplanting

The transplanting of the seedlings was performed as per the plan of layout in the afternoon of 15 November 2018. The row to row and plant to plant distance were maintained at 40 and 60 cm, respectively. 24days old healthy and uniform sized seedlings were selected. The seedbed was watered one hour before uprooting the

seedlings to minimize the damage to the roots of the seedlings. Twelve plants were transplanted in each unit plot. The seedlings were watered immediately after transplanting. Watering was continued until the seedlings were well established and it was required for 6 days.

3.7 Gap filling

Very few seedlings were damaged after transplanting and such seedling was replaced by new seedlings from the same stock planted earlier on the border of the experimental plots. The seedlings were transplanted with a mass of root attached with a soil ball to avoid transplanting shock.

3.8 Weeding

The hand weeding was done 15 and 30 days after transplanting (DAT) to keep the plots free from weeds.

3.9 Earthing up

Earthing up was done at 20 and 30 days after transplanting (DAT) by taking the soil from the space between the rows by a small spade.

3.10 Irrigation

Light watering was done every morning and afternoon following transplanting and was continued for 6 days for the early and well-established of the seedlings. Cabbage requires continuous availability of moisture in the soil. Heavy irrigation should however be avoided when heads have formed. Irrigation was also provided at 20 and 30days after transplanting followed by weeding and earthing up.

3.11 Control against insect and pests

Dursban 20EC @ 1 ml/liter water was sprayed once during the crop season so that termites can be controlled. Insect attack was a serious problem at the time of the establishment of the seedling. Ripcord @ 40ml/1 liter was applied thrice for controlling the caterpillar.

3.12 NAA application

NAA hormone was applied twice on the purple cabbage plant for higher growth and yield. It was sprayed properly on the whole plant by hand sprayer at 30 and 45 days old plant. When the hormone was sprayed, various careful measures

should be measured. The hormone is sprayed in the afternoon always for a favorable environment.

3.13 Fertilizer application

At the time of final land preparation whole vermicompost, TSP, MP, and one third of urea were given on the respective plot. Then rest of the area was given at two installments @15 and 35 days after transplanting.

3.14 Harvesting

Harvesting of the purple cabbage was not possible on a particular date because head initiation as well as head at marketable size in different plants were not uniform or similar probably due to different management practices and other factors. Only the compact marketable heads were harvested with 15 cm long fleshy stalk by using a sharp knife. Before harvesting the cabbage head, the compactness of the head was tested by pressing with thumbs. In this experiment. 1st harvest was done 74 DAT.

3.15 Data recorded-

The following observations on the characters of growth and development of plants were recorded at different growth stages and maturity on five randomly selected plants to each treatment in each replication and also for avoiding border effect. The head yield of purple cabbage was recorded plot-wise for estimating the hectare yield of purple cabbage. The selected plants were tagged for recording the details of observations. The observations are given below:

3.15.a Pre-harvest observations-

i. Plant height
ii. Leaf number/plant
iii. Leaf length
iv. Leaf breadth
v. Days of 1st head formation
vi. Canopy/plant

3.15.b Post-harvest 0bservations-

i. The whole weight of cabbage
ii. Unfolded leaf number
iii. Unfolded leaf weight
iv. Head fresh weight
v. Head length
vi. Head breadth
vii. Root length
viii. Stem diameter
ix. The dry weight of cabbage
x. Yield/plot
xi. Yield/hectare

3.15.c Chemical observations-

i. Iron (Fe)
ii. Beta (β) carotene

The whole procedure of data collection is given below:

3.15.a Pre-harvest observations-

3.15.a.i Plant height

The height of the plant was measured from the ground up to the height of apical bud with the help of a meter scale and the average values were worked out. Plant height was also recorded at a 20-days interval starting from 20 DAT up to 60 days and at harvest to observe the growth rate of the purple cabbage plants.

3.15.a.ii Number of leaves/plant

The open leaves of the selected plants were counted. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot at a 10-days interval starting from 20 days after transplanting (DAT) up to 50 days and at harvest.

3.15.a.iii Length of the largest leaf

The distance from the base of the petiole to the tip of the largest leaf was considered the length of the leaf. It was measured with a meter scale and was

recorded in centimeter (cm). Data were recorded as the average of 5 leaves selected at random from the inner rows plant of each plot at a 10-day interval starting from 30 days after transplanting (DAT) up to 50 days and at harvest.

3.15.a.iv The breadth of the largest leaf

The breadth of the largest leaf was recorded as the average of 5 leaves selected at random from the inner rows plant of each plot at a 10-day interval starting from 30 days after transplanting (DAT) up to 50 days and at harvest.

3.15.a.v Days from transplanting to head formation

Each plant of the experiment plot was kept under close observation to count days required for head formation. The total number of days from the date of transplanting to the visible head formation was recorded. 1st head was initiated at 45 days after transplanting (DAT).

3.15.a.vi Canopy/plant

The canopy of 5 selective plants was measured by the meter scale from the multiplication horizontal and vertical distance at 20, 40, and 60 DAT. This canopy was measured carefully and recorded in cm^2. Average data was recorded statistically.

3.15.b Post-harvest observations-

3.15.b.i The whole weight of cabbage

The whole weight of cabbage (leaf +head) per plant was recorded at the time of harvest from the average of five (5) selected plants in grams (g) with a beam balance. Average data were recorded carefully.

3.15.b.ii Unfolded leaf number

Unfolded leaves were trimmed first then counted at the time of harvest from the average of five selected plants in number. Average data were recorded.

3.15.b.iii Unfolded leaf weight

The unfolded leaves were trimmed first and weighed at the time of harvest from the average of five selected plants in grams with a beam balance. Average data were recorded carefully.

3.15.b.iv Head fresh weight

The fresh weight of head per plant was recorded at the time of harvest cabbage from the average of five (5) selected plants in grams (gm) with a beam balance. Average data were recorded carefully.

3.15.b.v Head length

The length of the head was measured at the point where the central head was cut off. The length was measured by the slide calipers from the base to the top level of the head and average data were recorded carefully.

3.15.b.vi Head breadth or girth

The breadth of the head was measured at the point where the central head was cut off. The breadth was measured by the meter scale of the top level of the head. Average data were recorded.

3.15.b.vii Root length

At first, the selected plant roots were uprooted from the field. The length of the root was taken from the ground level to the base of the tip of the root during harvesting. A meter scale was used for this and was expressed centimeter (cm).

3.15.b.viii Diameter of stem

The diameter of the stem was measured at the point where the central head was cut off. The diameter of the stem was recorded in three dimensions with scale and the average of three figures was taken into account in centimeter (cm).

3.15.b.ix The dry weight of cabbage (Head + leaves)

At first selected head and leaves were collected, cut into pieces, and was dried under sunshine for 3 days and then dried in an oven at 70^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken, measured, and expressed in gram (g).

3.15.b.x Yield/plot

The fresh weight of compact head at harvest after removing the loose leaves, stem, and root was recorded as the average of 5 plants selected at random from each unit plot. The weight of the total head of purple cabbage was recorded immediately after the harvest of the crop and expressed in a kilogram (kg).

3.15.b.xi Marketable yield/hectare

The weight of all compact head excluding leaves, stem, and root that produced in a plot was taken and converted into yield per hectare of the head of red-purple cabbage and was expressed in a ton. The weight of the total head was recorded immediately after the harvest of the crop.

3.15.c. Chemical observations-

3.15.c.i The iron content of the head

This iron content of cabbage was measured by UV-Spectrophotometer at the institute of food science and technology in Bangladesh Council of Scientific and Industrial Research (BCSIR). It was measured by mg /100gm.

3.15.c.ii The β- carotene content of head

This beta carotene content of cabbage was measured by UV-Spectrophotometer at the institute of food science and technology in Bangladesh Council of Scientific and Industrial Research (BCSIR). It was measured by µg/100gm.

3.16 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the level of significance of the different levels of nutrient sources i.e. fertilizers and NAA on growth and yield contributing characters of purple cabbage. The analysis was performed by F-test and the significance of the difference between pairs of treatment means was evaluated by the Least Significance Difference (LSD) test at a 5% level of significance. (Gomez and Gomez, 1984).

CHAPTER-IV

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) of the data on different parameters of Purple cabbage is given in Appendix (IV-XXIX). The data recorded on various characters during the course of investigation entitled "Growth and yield of purple cabbage influenced by nutrient sources and NAA" have been presented in this chapter along with appropriate tables and figures under the following heads:

4.1 Plant height

Effect of Nutrient sources

Plant height of purple cabbage varied statistically due to the different levels of NPK and vermicompost at 20, 40, and 60 DAT, respectively (Appendix IV-VI). Combine mixture of vermicompost and NPK doses treatment gave the maximum (19.08 cm) plant at 20 DAT while control treatment gave the minimum (18.00 cm) plant height. The tallest (18.00 cm) plant was observed from treatment F_3. F_3 treatment also gave the maximum plant height (22.75cm) which was statistically identical (21.75cm) with F_2 treatment and the minimum plant (19.08 cm) was from the F_0 treatment at 40 DAT (Figure 2). At 60DAT the tallest plant (31.33 cm) was recorded from the treatment F_3 the minimum plant (24.83 cm) was from the F_0 treatment which was statistically identical (26.00cm) with F_1 treatment. The results indicated that the combine mixture of vermicompost and NPK doses help to increases plant height by developing vegetative growth and the tallest plant was recorded in that condition (Ahmed *et al.* 2017).

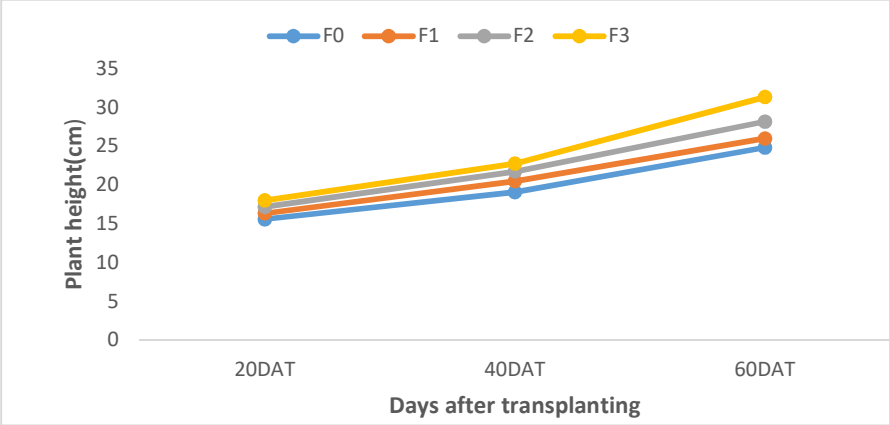


Figure 2: **Effect of fertilizer on plant height at different days after transplanting (DAT) of purple cabbage**

Here, F_0: control, F_1: vermicompost F_2: doses of NPK, F_3: ½ vermicompost and ½ doses of NPK

Effect of NAA

The plant height of cabbage varied significantly due to the different levels NAA at 20, 40, and 60 DAT (Fig. 3). At 40ppm NAA dose gave the maximum plant height (17.50 cm) and it was observed in N_2 treatment which was statistically identical (17.42cm) with N_3 treatment and minimum plant (15.67 cm) was observed in N_0 treatment at 20 DAT. At 40 DAT plant height is maximum in 40 ppm which was statistically identical (21.42cm) with N_3 treatment and minimum in 0 ppm or control condition (19.75cm). The maximum plant (29.00 cm) was observed in N_2 treatment and the minimum plant (25.83 cm) was observed in N_0 treatment at 60 DAT. At N_2 treatment (80 ppm) NAA gradually lowers the plant height which was statistically identical (27.25cm) with N_1 treatment (Figure 3).

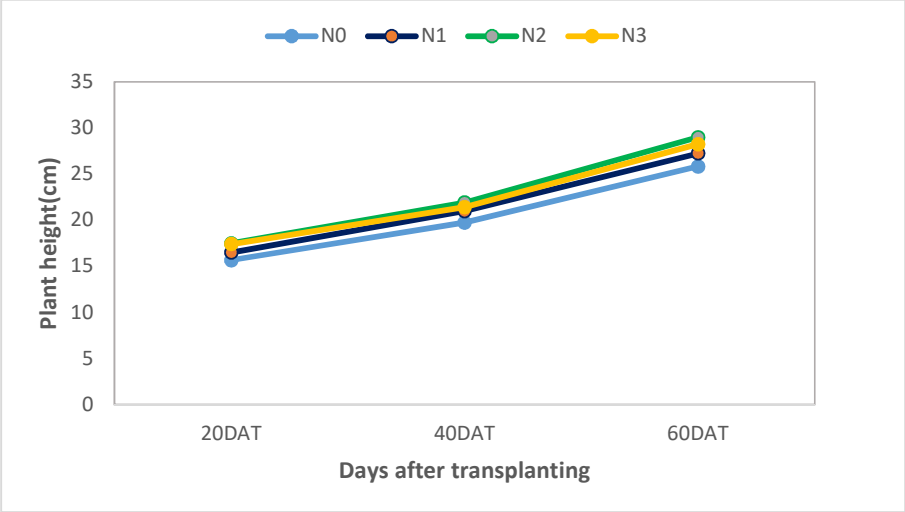


Figure 3: Effect of NAA on plant height at different days after transplanting (DAT) of purple cabbage

Here, N_0: 0 ppm NAA, N_1: 20 ppm NAA, N_2: 40 ppm NAA, N_3: 80 ppm NAA

The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of plant height at 20, 40, and 60 DAT (Table 2). At 20, 40, 60 DAT the maximum plant (20.00cm, 25.67cm, and 35.67cm respectively) was observed from F_3N_2 (½ vermicompost and ½ doses of NPK + 40ppm NAA), and the minimum plant (14.33cm, 18.00cm, and 24.33cm, respectively) was found from F_0N_0 (No nutrient sources and No NAA dose i.e. control condition) treatments. Vermicompost increases the vegetative growth and NAA increases the leaf epinasty.

Table 2: Combined effect of nutrient sources and NAA on plant height of Purple cabbage

Treatment Combination	Plant height (cm) at		
	20DAT	40DAT	60DAT
F_0N_0	14.33±0.33g	18.00±0.58f	24.33±0.88g
F_0N_1	15.67±0.33f	19.33±0.33def	25.33±0.88efg
F_0N_2	15.67±0.33f	19.00±0.58ef	24.67±0.67g
F_0N_3	16.67±0.33def	20.00±0.58de	25.00±1.15fg
F_1N_0	15.67±0.33f	20.00±0.58de	25.00±0.58fg
F_1N_1	16.33±0.33ef	20.67±0.33cd	26.33±0.88efg
F_1N_2	16.67±0.33def	20.67±0.33cd	26.33±0.67efg
F_1N_3	16.67±0.33def	20.67±0.33cd	26.33±0.33efg
F_2N_0	16.33±0.33ef	20.67±0.67cd	26.67±0.67efg
F_2N_1	16.67±0.33def	22.00±0.58bc	27.67±0.67cde
F_2N_2	17.67±0.33bcd	22.33±0.67b	29.33±1.33cd
F_2N_3	18.00±0.00bc	22.00±0.00bc	29.00±0.58cd
F_3N_0	16.33±0.33ef	20.33±0.33de	27.33±0.33def
F_3N_1	17.33±0.33cde	22.00±0.00bc	29.67±0.33c
F_3N_2	20.00±0.00a	25.67±0.33a	35.67±0.33a
F_3N_3	18.33±0.33b	23.00±0.00b	32.67±0.33b
Significance level	***	***	***

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.

$F_{0:}$ control, $F_{1:}$ vermicompost $F_{2:}$ doses of NPK, $F_{3:}$ ½ vermicompost and ½ doses of NPK

$N_{0:}$ 0 ppm NAA, $N_{1:}$ 20 ppm NAA, $N_{2:}$ 40 ppm NAA, $N_{3:}$ 80 ppm NA

4.2 Number of leaves/plant

Effect of Nutrient sources

The number of leaves of purple cabbage varied statistically due to the different levels of NPK and vermicompost at 30, 40, and 50 DAT (Appendix VII-IX). The combine mixture of vermicompost and NPK doses treatment gave maximum number of leaves at 30 DAT, while control treatment gave the minimum number of leaves. The maximum number of leaves/plant was observed from treatment F_3 which was statistically identical with F_1 treatment. F_3 treatment also gave the maximum leaf number and the minimum leaf number was from the F_0 treatment at 40 DAT (Figure 4). At 40DAT F_1 and F_2 are statistically identical. At 60 DAT the maximum leaf number of plants was recorded from the treatment F_3 which was statistically identical with F_1 and F_2 treatment the minimum plant leaves were from the F_0 treatment. The results indicated that the mixture of vermicompost and NPK doses help to increases the leaf number/plant and the maximum leaf number was recorded in that condition.

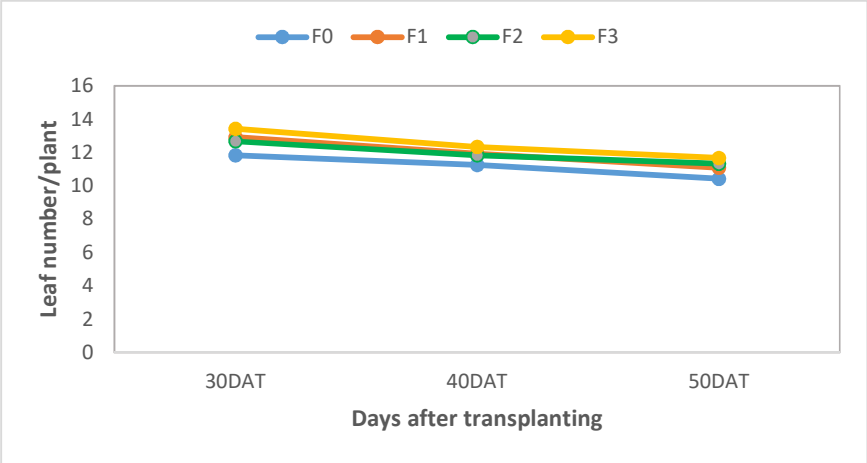


Figure 4: Effect of fertilizer on leaf number at different days after transplanting (DAT) of purple cabbage

F_0: control, F_1: vermicompost F_2: doses of NPK, F_3: ½ vermicompost and ½ doses of NPK

Effect of NAA

The leaf of cabbage varied significantly due to the different levels of NAA at 30, 40, and 50 DAT. The treatment 40ppm NAA dose gave the maximum leaf

number, which was statistically identical with N_1 and N_3 treatment and minimum leaf number were observed in N_0 treatment at 30 DAT. At 40 DAT maximum leaf number /plant in 40 ppm and minimum in 0 ppm or control condition. N_1 and N_3 treatments are statistically identical to each other at 40DAT. At 50 DAT leaf numbers were gradually higher than 30 DAT and 40 DAT (figure 5). The maximum leaf number was observed in N_2 treatment which was statistically identical with N_1 treatment and the minimum leaves were found in N_0 treatment at 50 DAT. At N_3 treatment (80 ppm) NAA gradually minimize the plant leaf number than N_2 treatment.). Findings revealed that the applied vermicompost affected the leaf characteristics i.e. number of produced leaves, leaf area, fresh and dry mass (Pour *et al*. 2013).

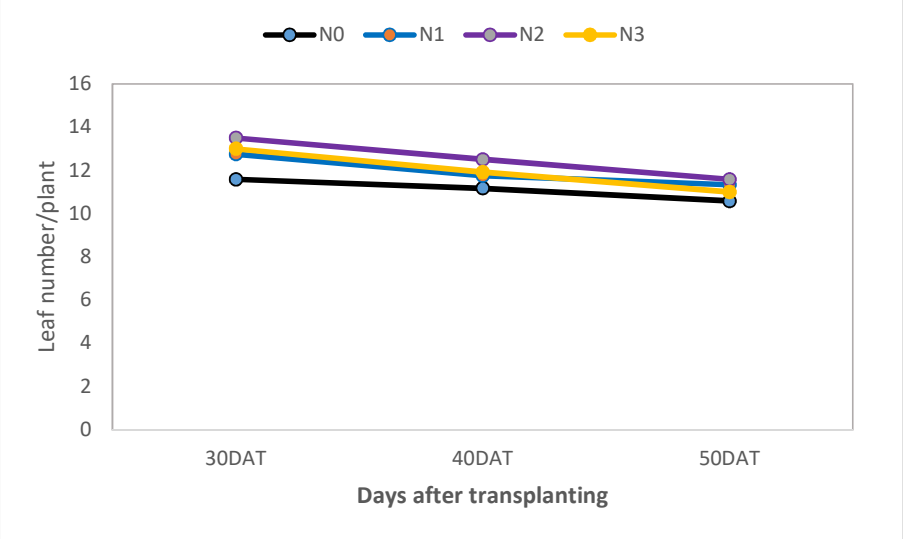


Figure 5: Effect of NAA on leaf number at different days after transplanting (DAT) of purple cabbage

Here, N_0: 0 ppm NAA, N_1: 20 ppm NAA, N_2: 40 ppm NAA, N_3: 80 ppm NAA

The combined effect of different levels of vermicompost, NPK doses and NAA showed statistically significant variation in terms of leaf number of Purple cabbage at 20, 40, and 60 DAT. At 20, 40, and 60 DAT the maximum leaf number was observed from F_3N_2 (½ vermicompost and ½ recommended dose of NPK + 40ppm NAA), and the minimum leaf number were found from F_0N_0 (No nutrient sources and No NAA dose i.e. control condition) treatment (Table 3).

Table 3: Combined effect of nutrient sources and NAA on leaf number of Purple cabbage

Treatment Combination	Leaf number at		
	30DAT	40DAT	50DAT
F_0N_0	10.67±0.67e	11.00±0.00bc	10.00±0.00c
F_0N_1	12.00±0.00cd	11.00±0.00bc	10.67±0.33bc
F_0N_2	12.33±0.67bcd	12.00±1.15bc	11.00±0.58bc
F_0N_3	12.33±0.33bcd	11.00±0.00bc	10.00±0.00c
F_1N_0	12.33±0.33bcd	11.33±0.33bc	10.67±0.33bc
F_1N_1	13.33±0.33bc	12.33±0.33ab	11.33±0.33b
F_1N_2	13.00±0.58bc	12.00±0.58bc	11.33±0.67b
F_1N_3	13.00±0.00bc	12.00±0.00bc	11.00±0.00bc
F_2N_0	12.00±0.00cd	10.67±0.33c	10.67±0.33bc
F_2N_1	12.33±0.67bcd	12.00±0.58bc	11.67±0.33ab
F_2N_2	13.33±0.33bc	12.33±0.33ab	11.33±0.33b
F_2N_3	13.00±0.00bc	12.33±0.33ab	11.67±0.33ab
F_3N_0	11.33±0.33de	11.67±0.33bc	11.00±0.58bc
F_3N_1	13.33±0.33bc	11.67±0.88bc	11.67±0.33ab
F_3N_2	15.33±0.33a	13.67±0.33a	12.67±0.33a
F_3N_3	13.67±0.33b	12.33±0.33ab	11.33±0.33b
Significance level	***	**	***

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.

F_0: control, F_1: vermicompost F_2: doses of NAA, F_3: ½ vermicompost and ½ doses of NPK

N_0: 0 ppm NAA, N_1: 20 ppm NAA, N_2: 40 ppm NAA, N_3: 80 ppm NAA

4.3 Leaf length

Effect of nutrient sources

The leaf length of the specific plant of purple cabbage varied statistically due to the different levels of NPK and vermicompost at 40, and 50 DAT (Appendix X-XI). A mixture of vermicompost and NPK doses treatment gave the broadest leaf (22.25cm) at 40 DAT while control treatment gave the shortest leaf (17.00cm). The broadest leaf was observed from treatment F_3. F_3 treatment also gave the broadest (29.42cm) and the shortest leaf (26.08cm) was from the F_0 treatment at 50 DAT (Table 4). The results indicated that the combine mixture of vermicompost and NPK doses help to increases the length of the cabbage leaf and the broader leaves length was recorded in that condition.

Effect of NAA

The leaf length of cabbage varied significantly due to the different levels of NAA at 40 and 50 days after transplanting(DAT). 40ppm NAA dose gave the broadest leaf (21.67cm) and it was observed in N_2 treatment which was statistically identical (21.58cm) with N_3 treatment and shortest leaf (18.17cm) was observed in N_0 treatment at 40 DAT. At 50 DAT broadest leaf (28.75cm) was found in 40 ppm and the shortest leaf (27.08cm) in 0 ppm or control condition. At N_3 treatment (80 ppm) NAA gradually lowers the plant leaf length than N_2 treatment. At 50 DAT N_0, N_1, N_2, and N_3 treatments are statistically identical (Table 5).

The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of leaf length of Purple cabbage at 40 and 50 DAT (Table 6). At 40 and 50 DAT, the broader leaf length (25.67cm and 32.67cm) were observed from F_3N_2 (½ vermicompost and ½ doses of NPK + 40ppm NAA) and the shorter leaf length (16.00cm and 26.00cm) were found from F_0N_0 (No nutrient sources and No NAA dose i.e. control condition) treatment.

Table 4: Effect of nutrient sources on leaf length and breadth of Purple cabbage

Treatment	Leaf length (cm) at		Leaf breadth (cm) at	
	40DAT	50DAT	40DAT	50DAT
F_0	17.00±0.42c	26.08±0.38c	11.75±0.41c	18.08±0.43b
F_1	20.08±0.56b	27.50±0.65bc	13.92±0.34b	19.33±0.62b
F_2	21.33±0.68ab	29.08±0.48ab	17.58±0.78a	22.67±0.71a
F_3	22.25±0.91a	29.42±0.84a	18.25±0.91a	24.00±0.98a
Significance level	***	***	***	***

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.

F_0: control, F_1: vermicompost F_2: doses of NAA, F_3: ½ vermicompost and ½ doses of NPK

Table 5: Effect of NAA on leaf length and breadth of Purple cabbage

Treatment	Leaf length(cm) at		Leaf breadth(cm) at	
	40DAT	50DAT	40DAT	50DAT
N_0	18.17±0.63b	27.08±0.45	13.25±0.90	19.33±0.73b
N_1	19.75±0.72ab	27.75±0.78	15.17±0.90	20.50±0.81ab
N_2	21.67±0.90a	28.75±0.92	16.58±1.12	23.25±1.07a
N_3	21.58±0.68a	28.50±0.57	16.50±0.87	21.00±1.02ab
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.

N_0: 0 ppm NAA, N_1: 20 ppm NAA, N_2: 40 ppm NAA, N_3: 80 ppm NAA

4.4 Leaf Breadth

Effect of nutrient sources

The leaf breadth of the specific plant of purple cabbage varied statistically due to the different levels of NPK and vermicompost at 40 and 50 DAT (Appendix XII-XIII). A mixture of vermicompost and NPK doses treatment gave the widest leaf (18.25cm) at 40 DAT which was statistically identical (17.58cm) with F_2 treatment while control treatment gave the shortest leaf (11.75cm). The widest

leaf was observed from treatment F_3. F_3 treatment also gave the broadest leaf (24.00cm) which was statistically identical (22.67cm) with F_2 treatment and the shortest leaf (18.08cm) was from the F_0 treatment which was statistically identical (19.33cm) with F_1 treatment at 50 DAT (Table 4). The results indicated that the combine mixture of vermicompost and NPK doses help to increases the breadth of the cabbage leaf.

Effect of NAA

The leaf breadth of the specific plant of purple cabbage varied statistically due to the different levels of NPK and vermicompost at 40 and 50 DAT (Appendix XII-XIII). A mixture of vermicompost and NPK doses treatment gave the widest leaf (16.58cm) at 40 DAT while control treatment gave the shortest leaf (13.25cm). The widest leaf was observed from treatment N_2 (40ppm) which was statistically identical (16.50cm) with N_3 treatment. N_2 treatment (40 ppm) also gave the broadest leaf (23.25cm) and the shortest leaf (19.33cm) was from the N_0 treatment (0 ppm) at 50 DAT (Table 5). At N_3 treatment (80 ppm) NAA gradually lowers the plant leaf breadth than N_2 treatment.

The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of leaf length of Purple cabbage at 40 and 50 DAT (Table 6). At 40 and 50 DAT, the breadth of leaves (21.33cm and 28.33cm) were observed from F_3N_2 (½ vermicompost and ½ recommended dose of NPK + 40ppm NAA) and the shorter leaves breadth (10.00cm and 17.33cm) were found from F_0N_0 (No nutrient sources and No NAA dose i.e. control condition) treatment.

Table 6: Combined effect of nutrient sources and NAA on leaf length and breadth of Purple cabbage

Treatment Combination	Leaf length (cm) at		Leaf breadth (cm) at	
	40DAT	50DAT	40DAT	50DAT
F_0N_0	16.00±0.58f	26.00±0.58de	10.00±0.58g	17.33±0.33f
F_0N_1	17.00±0.58ef	26.67±1.20cde	12.00±0.58fg	17.33±0.67f
F_0N_2	18.67±0.88def	25.00±0.00e	12.00±0.58fg	19.33±0.33def
F_0N_3	18.33±0.333def	26.67±0.67cde	13.00±0.58efg	18.33±1.45ef
F_1N_0	18.67±0.88def	27.33±0.88be	12.67±0.67efg	18.33±1.20ef
F_1N_1	20.00±1.00be	28.67±2.67bcd	14.00±0.58def	19.67±0.33cf
F_1N_2	20.00±1.00be	27.00±0.58be	14.33±0.33def	21.00±0.58bf
F_1N_3	21.67±1.33bcd	27.00±0.00be	14.67±0.67def	18.33±2.03ef
F_2N_0	19.00±1.15cf	27.33±0.67be	14.67±1.67def	21.00±1.53bf
F_2N_1	21.00±1.53bcd	28.67±0.88bcd	17.33±1.67bcd	22.00±1.73be
F_2N_2	22.33±1.20bc	30.33±0.33ab	18.67±0.67abc	24.33±0.67b
F_2N_3	23.00±0.58ab	30.00±1.00abc	19.67±0.67ab	23.33±1.45bc
F_3N_0	19.00±1.73cf	27.67±1.45be	15.67±2.19cde	20.67±1.76bf
F_3N_1	21.00±1.53bcd	27.00±1.53be	17.33±2.03bcd	23.00±1.15bcd
F_3N_2	25.67±0.67a	32.67±0.88a	21.33±0.67a	28.33±0.88a
F_3N_3	23.33±0.33ab	30.33±0.33ab	18.67±0.67abc	24.00±0.58b
Significance level	***	***	***	***

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.

F_0: control, F_1: vermicompost F_2: doses of NPK, F_3: ½ vermicompost and ½ doses of NPK

N_0: 0 ppm NAA, N_1: 20 ppm NAA, N_2: 40 ppm NAA, N_3: 80 ppm NAA

4.5 Canopy of plant

Effect of Nutrient sources

The canopy of the plant of purple cabbage varied statistically due to the different levels of NPK and vermicompost at 20, 40, and 60 DAT (Appendix XIV-XVI). The mixture of vermicompost and NPK doses treatment gave the highest (765.03 cm^2) plant canopy at 20 DAT while control treatment gave the lowest (608.90 cm^2) plant canopy. The highest (765.03 cm^2) plant canopy was observed from treatment F_3 which was statistically identical with F_1 and F_2 treatments. F_3 treatment also gave the highest plant canopy (1250.14cm^2) and the shortest plant (994.05cm^2) canopy was from the F_0 treatment at 40 DAT which all treatments are statistically identical (Table 7). At 60DAT the highest plant canopy (2895.13cm^2) was recorded from the treatment F_2 the shortest plant (2055.88cm^2) was from the F_0 treatment. The effects of vermicompost on plant growth and development not only were nutritional but also hormonal and biochemical and the utilization of high levels of vermicompost, especially at the seedling stage, neither is not only economic but also may have adverse effects on the plant growth and development (Pour *et al*. 2013).

Table 7: Effect of fertilizer on plant canopy at 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	**	***	***

Here, F_0: control, F_1: vermicompost F_2: doses of NPK, F_3: ½ vermicompost and ½ doses of NPK

Effect of NAA

The plant canopy of cabbage varied significantly due to the different levels NAA at 20, 40, and 60 DAT (Figure 6). 40ppm NAA dose gave maximum plant canopy (806.93cm^2) and it was observed in N_2 treatment and minimum plant canopy (643.75cm^2) was observed in N_1 treatment which was statistically identical with N_0 treatment at 20 DAT. At 40 DAT plant canopy maximum in 40 ppm and minimum in 0 ppm or control condition. All treatments are statistically identical to each other at 40 DAT and 60 DAT. At 60 DAT plant canopy was gradually higher than 20 DAT and 40 DAT. The maximum plant canopy (2764.69cm^2) was observed in N_2 treatment and the minimum plant canopy (2308.15cm^2) at 60 DAT. At N_3 treatment (80 ppm) NAA gradually lowers the plant canopy than N_2 treatment. NAA induced a downward movement of the wrapper leaves of decapitated plants and the plants with the entire heads and in the leaves of young seedlings (Kato and Sooen, 1980)

The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of plant canopy of Purple cabbage at 20, 40, and 60 DAT (Table 8). At 20, 40, and 60 DAT the maximum plant canopy (926.60cm^2, 1464.90cm^2 and 3496.40cm^2 respectively) were observed from F_3N_2 (½ vermicompost and ½ recommended dose of NPK + 40ppm NAA) and the minimum plant (502.73cm^2, 818.13cm^2, 1699.13cm^2 respectively) were found from F_0N_0 (No nutrient sources and No NAA dose i.e. control condition) treatment.

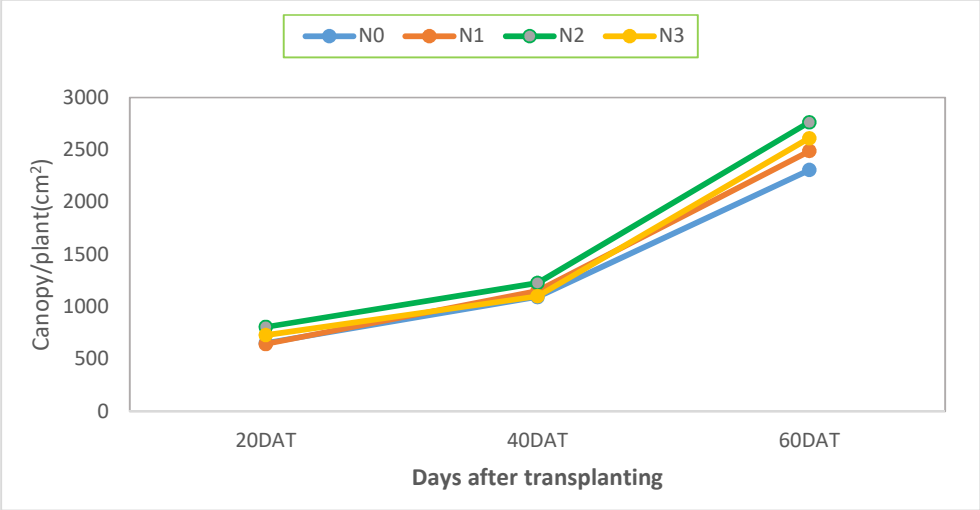


Figure 6: Effect of NAA on plant canopy at different days after transplanting (DAT) of purple cabbage

Here, $N_{0:}$ 0 ppm NAA, $N_{1:}$ 20 ppm NAA, $N_{2:}$ 40 ppm NAA, $N_{3:}$ 80 ppm NAA

Table 8: 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 dissimilar letter (s) differ significantly as per the 0.05 level of probability analyzed by DMRT.

F_0: control, F_1: vermicompost F_2: doses of NAA, F_3: ½ vermicompost and ½ doses of NPK

N_0: 0 ppm NAA, N_1: 20 ppm NAA, N_2: 40 ppm NAA, N_3: 80 ppm NAA

4.6 The whole weight of cabbage

Effect of Nutrient sources

Purple cabbage was 1st harvested at 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 time being of harvest. A mixture of vermicompost and NPK doses treatment gave maximum weight (891.32gm) while control treatment gave minimum weight (551.28gm) (Table 9). The maximum weight of cabbage was observed from treatment F_3 which was statistically identical with F_2 treatment and the minimum was observed from F_0 treatment which was statistically identical with F_1 treatment (Appendix XVII). The results indicated that the mixture of vermicompost and NPK doses help to increases the whole weight of purple cabbage and the control condition does the minimum weight.

Effect of NAA

The whole weight of cabbage varied significantly due to the different levels of NAA. At 40ppm NAA dose gave maximum weight (831.41gm) of cabbage and it was observed in N_2 treatment which was statistically identical with N_3 treatment and minimum weight (580.30gm) was observed in N_0 treatment at the different time being of harvest. At N_1 treatment (20ppm) whole weight (709.75gm) was gradually higher than N_0 treatment and lower than N_2 treatment. At N_3 treatment (80 ppm) NAA gradually lowers the whole weight of cabbage than N_2 treatment (Table 10). So it can be said that N_2 treatment is the best treatment.

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 11). At harvesting time average maximum cabbage weight (1100.60gm) was observed from F_3N_2 (½ vermicompost and ½ recommended dose of NPK + 40ppm NAA) and the

minimum weight (314.70gm) was found from F_0N_0 (No nutrient sources and No NAA dose i.e. control condition) treatment. It was proved that maximum cabbage weight was found in the F_3N_2 combination.

4.7 Unfolded leaf number

Effect of Nutrient sources

The unfolded leaf number of purple cabbage was counted after the harvest of cabbage. The unfolded leaf number can be varied statistically due to the different levels of NPK and vermicompost at the different time being of harvest. Recommended doses of NPK treatment gave the maximum leaf number as well as unfolded leaf number (9.67) while control treatment gave the minimum (7.42) (Table 9). The maximum unfolded leaves of cabbage were observed from treatment F_2 and the minimum was observed from F_0 treatment (Appendix XVIII). At F_1 and F_3 treatment, leaf numbers were statistically identical (8.58). The results indicated that doses of NPK help to increase the unfolded leaf number of purple cabbage and the control condition does the minimum number.

Effect of NAA

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 being of harvest. At N_1 treatment (20ppm) leaf number (8.75) was gradually higher than N_0 treatment and lower than N_2 treatment (Table 10). At N_3 treatment (80 ppm) NAA gradually lowers the unfolded leaf number (8.58) of cabbage than N_2 treatment. So it can be said that N_2 treatment is the best treatment. All treatments are statistically identical.

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 11). 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.

4.8 Unfolded leaf weight

Effect of Nutrient sources

The weight of unfolded leaves of purple cabbage was done after the harvest of cabbage. The weight of unfolded leaves can be varied statistically due to the different levels of NPK and vermicompost at the different time being of harvest. The recommended dose of NPK treatment gave maximum weight (269.40gm) by thickening the leaves while control treatment gave the lowest weight (166.00gm) (Table 9). The maximum weight of unfolded leaves of cabbage was observed from F_2 treatment and the minimum was observed from F_0 treatment (Appendix XIX). The results indicated that NPK doses help to increase the unfolded leaf weight of purple cabbage and the control condition does the minimum weight.

Effect of NAA

The weight of unfolded leaves of purple cabbage was done after the harvest of cabbage. The treatment 40ppm NAA dose gave the maximum leaf weight (222.15gm) of cabbage and it was observed in N_2 treatment and minimum weight (209.58gm) was observed in N_1 treatment at the different time being of harvest. At N_0 treatment (20ppm) unfolded leaf weight (210.38gm) was gradually higher than N_1 treatment and lower than N_2 treatment. At N_3 treatment (80 ppm) NAA gradually lowers the weight (221.14gm) of cabbage than N_2 treatment. So it can be said that N_2 treatment is the best treatment. All treatments are statistically identical (table 10).

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 11). At harvesting time average maximum unfolded leaf weight (302.93gm) was observed from F_2N_2

(NPK doses + 40ppm NAA) and the minimum weight (147.63gm) was found from F_0N_1 (No nutrient sources and 20ppm NAA dose i.e. control condition) treatment. It was proved that the maximum unfolded leaf weight of cabbage was found in the F_2N_2 combination.

4.9 Head fresh weight

Effect of Nutrient sources

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 time being of harvest. A mixture of vermicompost and NPK doses treatment gave the maximum weight (657.12gm) while control treatment gave the minimum weight (385.28gm) (Table 9). The maximum weight of cabbage was observed from treatment F_3 which was statistically identical with treatment F_2 and the minimum was observed from F_0 treatment which was statistically identical with treatment F_1 (Appendix XX). The results indicated that the mixture of vermicompost and NPK doses help to increase the head weight of purple cabbage and the control condition does the minimum weight.

Effect of NAA

The head weight of cabbage varied significantly due to the different levels of NAA. The treatment 40ppm NAA dose gave the maximum head weight (609.26gm) of cabbage and it was observed in N_2 treatment which was statistically identical with treatment N_1, N_3, and minimum weight (369.92gm) was observed in N_0 treatment at the different time being of harvest. At N_1 treatment (20ppm) head weight (500.17gm) was gradually higher than N_0 treatment and lower than N_2 treatment. At N_3 treatment (80 ppm) NAA gradually lowers the head weight (556.31gm) of cabbage than N_2 treatment (Table 10). So it can be said that N_2 treatment is the best treatment.

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 11). At harvesting time maximum head weight (883.07gm) was observed from F_3N_2 (½ vermicompost and ½ doses of NPK + 40ppm NAA) and the minimum weight (159.43gm) was found from F_0N_0 (No nutrient sources and No NAA dose i.e. control condition) treatment. It was proved that the maximum cabbage weight was found in the F_3N_2 combination.

Table 9: Effect of nutrient sources 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	***	***	**	***

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.

$F_{0:}$ control, $F_{1:}$ vermicompost $F_{2:}$ doses of NPK, $F_{3:}$ ½ vermicompost and ½ doses of NPK

Table 10: Effect of 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)
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) are statistically identical and those having dissimilar letter (s) differ significantly as per the 0.05 level of probability analyzed by DMRT.

$N_{0:}$ 0 ppm NAA, $N_{1:}$ 20 ppm NAA, $N_{2:}$ 40 ppm NAA, $N_{3:}$ 80 ppm NAA

Table 11: 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.

F_0: control, F_1: vermicompost F_2: doses of NPK, F_3: ½ vermicompost and ½ doses of NPK

N_0: 0 ppm NAA, N_1: 20 ppm NAA, N_2: 40 ppm NAA, N_3: 80 ppm NAA

4.10 Head length

Effect of nutrient sources

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 treatment gave the maximum length (9.95cm) while control treatment gave the minimum head length (4.73cm). The maximum head length was observed from treatment F_3 which was statistically identical with treatment F_2 (Table 12). At F_1 and F_2 treatments head lengths were higher than F_0 and lower than F_3 (Appendix XXI). The results indicated that the mixture of vermicompost and NPK doses help to increases the length of the cabbage head and the broader head length was recorded in that condition.

Effect of NAA

The head length of cabbage varied significantly due to the different levels of NAA after harvest. 40ppm NAA dose gave the maximum head length (8.87cm) and it was observed in N_2 treatment and the minimum length (7.31cm) was observed in N_0 treatment. At N_1 treatment, the head length was higher than N_0 but lower than N_2 (Table 13). At N_3 treatment (80 ppm) NAA gradually lowers the plant head length than N_2 treatment. So it can be said that N_2 treatment is the best treatment. All treatments are statistically identical to each other.

The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of head length of Purple cabbage (Table 14). The maximum head length (10.57cm) was observed from F_3N_2 (½ vermicompost and ½ doses of NPK + 40ppm NAA) and the minimum head length (3.43cm) were found from F_0N_0 (No nutrient sources and No NAA dose i.e. control condition) treatment. It was proved that the maximum head length was found in the F_3N_2 combination.

4.11 Head breadth

Effect of nutrient sources

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 treatment gave the maximum breadth (10.56cm) while control treatment gave the minimum head breadth (7.39cm). The maximum head breadth was observed from treatment F_3 which was statistically identical with F_2 treatment (Table 12). At F_1 and F_2 treatments head breadths were higher than F_0 and lower than F_3 (Appendix XXII). The results indicated that the mixture of vermicompost and NPK doses help to increase the breadth of the cabbage head.

Effect of NAA

The head breadth of cabbage varied significantly due to the different levels of NAA after harvest. 40ppm NAA dose gave the highest head breadth (10.12cm) and it was observed in N_2 treatment and the lowest breadth (8.77cm) was observed in N_0 treatment. At N_1 treatment, head breadth was higher than N_0 but lower than N_2 (Table 13). At N_3 treatment (80 ppm) NAA gradually lowers the plant head breadth than N_2 treatment. So it can be said that N_2 treatment is the best treatment. All treatments are statistically identical to each other.

The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of head breadth of Purple cabbage (Table 14). The higher head breadth (11.29cm) was observed from F_3N_2 (½ vermicompost and ½ doses of NPK + 40ppm NAA) and the shorter head breadth (6.68cm) was found from F_0N_0 (No nutrient sources and No NAA dose i.e. control condition) treatment. It was proved that the highest cabbage head breadth was found in the F_3N_2 combination.

4.12 Root length

Effect of nutrient sources

The root length of specific plants 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 root length (14.17cm) while control treatment gave the minimum root length (10.42cm). The maximum root length was observed from treatment F_3. At F_1 and F_2 treatments, root lengths were higher than F_0 and lower than F_3 (Table 12). F_1 and F_2 treatments were statistically identical to each other (Appendix XXIII). The results indicated that the mixture of vermicompost and NPK doses help to increase the length of cabbage root.

Effect of NAA

The root length of cabbage varied significantly due to the different levels of NAA after harvest. The treatment 40ppm NAA dose gave the maximum root length (13.33cm) and it was observed in N_2 treatment and the minimum length (11.17cm) was observed in N_0 treatment. At N_1 treatment, root length was maximum than N_0 which was statistically identical with N_3 treatment but minimum than N_2 (Table 13). At N_3 treatment (80 ppm) NAA gradually minimizes the root length than N_2 treatment. So it can be said that N_2 treatment is the best treatment.

The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of root length of Purple cabbage (Table 14). The maximum root length (16.00cm) was observed from F_3N_2 (½ vermicompost and ½ doses of NPK + 40ppm NAA) and the minimum root length (9.67cm) was found from F_0N_0 (No nutrient sources and No NAA dose i.e. control condition) treatment. It was proved that the maximum cabbage root length was found in the F_3N_2 combination.

4.13 Stem diameter

Effect of nutrient sources

The stem diameter of purple cabbage varied statistically due to the different levels of NPK and vermicompost at harvest time. The mixture of vermicompost and NPK doses treatment gave the maximum stem diameter (2.46cm) which was statistically identical with F2 treatment while control treatment gave the minimum stem diameter (1.79cm). The maximum stem diameter was observed from treatment F_3 (Table 12). At F_1 and F_2 treatments stem diameter was higher than F_0 and lower than F_3 (Appendix XXIV). The results indicated that the combine mixture of vermicompost and NPK doses help to increase the stem diameter of cabbage.

Effect of NAA

The stem diameter of cabbage varied significantly due to the different levels of NAA after harvest. The treatment 40ppm NAA dose gave the highest stem diameter (2.31cm) and it was observed in N_2 treatment and the lowest stem diameter (2.03cm) was observed in N_0 treatment (Table 13). At N_1 treatment stem diameter was higher than N_0 but lower than N_2. At N_3 treatment (80 ppm) NAA gradually lowers the cabbage stem diameter than N_2 treatment. So it can be said that N_2 treatment is the best treatment. All treatments are statistically identical to each other.

The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of stem diameter of Purple cabbage (Table 14). The maximum stem diameter (2.60cm) was observed from F_3N_2 (½ vermicompost and ½ doses of NPK + 40ppm NAA) and the minimum stem diameter (1.40cm) was found from F_0N_0 (No nutrient sources and No NAA dose i.e. control condition) treatment. It was proved that the maximum stem diameter of the cabbage plant was found in the F_3N_2 combination.

Table 12: Effect of nutrient sources on head length, head breadth, Root length, Stem diameter of Purple cabbage

Treatment	Head Length(cm)	Head Breadth(cm)	Root Length(cm)	Stem Diameter(cm)
F_0	4.73±0.47c	7.39±0.56c	10.42±0.31c	1.79±0.13c
F_1	8.48±0.54b	8.69±0.56b	12.00±0.55b	2.13±0.10b
F_2	9.87±0.06a	10.36±0.20a	12.75±0.39b	2.39±0.025a
F_3	9.95±0.15a	10.56±0.21a	14.17±0.53a	2.46±0.043a
Significance level	***	***	***	***

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.

F_0: control, F_1: vermicompost F_2: doses of NPK, F_3: ½ vermicompost and ½ doses of NPK.

Table 13: Effect of NAA on head length, head breadth, Root length, Stem diameter of Purple cabbage

Treatment	Head Length	Head Breadth	Root Length	Stem Diameter
N_0	7.31±0.86	8.77±0.64	11.17±0.53	2.04±0.14
N_1	8.07±0.79	9.12±0.51	12.08±0.48	2.16±0.13
N_2	8.87±0.54	10.12±0.41	13.33±0.58	2.31±0.09
N_3	8.78±0.61	8.99±0.62	12.75±0.64	2.26±0.08
Significance level	Non-significant	Non-significant	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.

N_0: 0 ppm NAA, N_1: 20 ppm NAA, N_2: 40 ppm NAA, N_3: 80 ppm NAA.

Table 14: Combined effect of nutrient sources and NAA on head length, head breadth, Root length, Stem diameter of Purple cabbage

Treatment Combination	Head Length(cm)	Head Breadth(cm)	Root Length(cm)	Stem Diameter(cm)
F_0N_0	3.43±0.03c	6.68±0.48	9.67±0.33a	1.40±0.10d
F_0N_1	3.63±0.30c	7.20±0.35	10.33±0.33ab	1.47±0.13d
F_0N_2	6.13±0.29b	8.93±1.22	11.33±0.67abc	2.23±0.03abc
F_0N_3	5.73±1.29b	6.75±1.85	10.33±0.88ab	2.07±0.24bc
F_1N_0	6.48±1.66b	7.88±2.33	10.33±1.33ab	2.10±0.30bc
F_1N_1	8.92±0.49a	8.99±0.76	12.67±1.33bcd	2.30±0.10abc
F_1N_2	8.83±0.70a	9.38±0.30	12.00±0.00abc	1.97±0.28c
F_1N_3	9.67±0.15a	8.50±0.42	13.00±1.00bcd	2.14±0.13abc
F_2N_0	9.63±0.07a	9.87±0.22	12.33±0.88abcd	2.33±0.07abc
F_2N_1	10.02±0.11a	10.44±0.44	12.00±0.58abc	2.43±0.03abc
F_2N_2	9.94±0.07a	10.87±0.49	14.00±0.58cde	2.43±0.03abc
F_2N_3	9.90±0.12a	10.27±0.33	12.67±0.88bcd	2.37±0.07abc
F_3N_0	9.71±0.18a	10.13±0.54	12.33±0.88abcd	2.31±0.10abc
F_3N_1	9.74±0.07a	10.38±0.45	13.33±0.67cd	2.45±0.07ab
F_3N_2	10.57±0.03a	11.29±0.05	16.00±0.00e	2.60±0.00a
F_3N_3	9.80±0.45a	10.44±0.33	15.00±1.00de	2.47±0.07ab
Significance level	***	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.

F_0: control, F_1: vermicompost F_2: doses of NPK, F_3: ½ vermicompost and ½ doses of NPK

N_0: 0 ppm NAA, N_1: 20 ppm NAA, N_2: 40 ppm NAA, N_3: 80 ppm NAA

4.14 The dry weight of cabbage

Effect of nutrient sources

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 (11.5g) while control treatment gave the minimum dry weight (8.5g). The maximum dry weight was observed from treatment F_1 (Table 14). At F_2 and F_3 treatments dry weight was higher than F_0 and lower than F_1 (Appendix XXV). The results indicated that vermicompost helps to increase the dry weight of cabbage.

Effect of NAA

The dry weight of cabbage varied significantly due to the different levels of NAA after harvest. The treatment 40ppm NAA dose gave the maximum dry weight (10.5g) and it was observed in N_2 and N_3 treatment and minimum dry weight (8.5g) were observed in N_0 treatment (Table 15). At N_1 treatment dry weight of cabbage was higher than N_0 but lower than N_2. At N_3 treatment (80 ppm) NAA gradually lowers the cabbage dry weight than N_2 treatment. So it can be said that N_2 treatment is the best treatment.

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 16). The maximum dry weight was observed from F_3N_2 (½ vermicompost and ½ doses of NPK + 40ppm NAA) which was statistically identical with F_2N_3, F_1N_1, F_1N_2, F_1N_3 treatments, and the minimum stem diameter (1.40cm) was found from F_0N_0 (No nutrient sources and no NAA dose i.e. control condition) treatment.

Table 15: Effect of nutrient sources on dry weight and, yield/plot of Purple cabbage

Treatment	Dry Weight(g)	Yield/Plot(kg)
F_0	8.50±0.26c	4.62±0.53b
F_1	11.50±0.26a	5.24±0.41b
F_2	9.50±0.50ab	6.68±0.24a
F_3	10.00±0.43b	7.89±0.59a
Significance level	***	***

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.

F_0: control, F_1: vermicompost F_2: doses of NPK, F_3: ½ vermicompost and ½ doses of NPK

Table 16: Effect of NAA on dry weight and, yield/plot of Purple cabbage

Treatment	Dry Weight(g)	Yield/Plot(kg)
N_0	9.00±0.30	4.44±0.53b
N_1	9.50±0.50	6.00±0.33a
N_2	10.50±0.50	7.31±0.65a
N_3	10.50±0.50	6.68±0.44a
Significance level	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.

N_0: 0 ppm NAA, N_1: 20 ppm NAA, N_2: 40 ppm NAA, N_3: 80 ppm NAA

4.15 Yield/plot

Effect of nutrient sources

The yield/plot of purple cabbage varied statistically due to the different levels of NPK and vermicompost. The combine mixture of vermicompost and NPK doses treatment gave the maximum yield (7.89kg) which was statistically identical with F_2 treatment (6.68kg) while control treatment gave the minimum yield (4.62kg) which was statistically identical with F_1 treatment (5.24kg) (Table 14). The maximum yield/plot was observed from treatment F_3 (Appendix XXVI).

Effect of NAA

The yield/plot of cabbage varied significantly due to the different levels of NAA after harvest. The treatment 40ppm NAA dose gave the maximum yield (7.31kg) and it was observed in N_2 treatment which was statistically identical with N_1 and N_3 treatments and the minimum yield was observed in N_0 treatment (4.44kg). At N_1 treatment yield/plot was higher than N_0 but lower than N_2 (Table 15). At N_3 treatment (80 ppm) NAA gradually lowers the cabbage yield than N_2 treatment. So it can be said that N_2 treatment is the best treatment.

The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of yield/plot of Purple cabbage (Table 16). The maximum yield/plot (10.60kg) was observed from F_3N_2 (½ vermicompost and ½ doses of NPK + 40ppm NAA) and the minimum yield (1.91kg) was found from F_0N_0 (No nutrient sources and No NAA dose i.e. control condition) treatment. It was proved that the maximum yield/plot of the cabbage plant was found in the F_3N_2 combination.

4.16 Yield/ha

Effect of nutrient sources

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 (27.38ton) which was statistically

identical with F_3 treatment while control treatment gave the minimum yield/plot (16.05ton) which was statistically identical with F_1 treatment (Appendix XXVII). The maximum yield was observed from treatment F_3. At F_2 and F_3 treatments yield/ha were higher than F_0 and lower than F_1 (figure 7). The results indicated that the Mixture of vermicompost and NPK doses help to increase the yield/ha of cabbage.

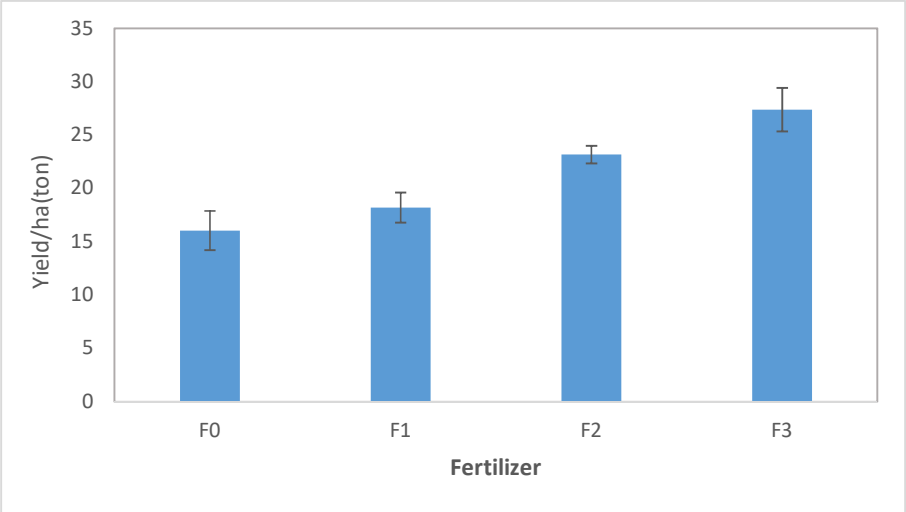


Figure 7: Effect of fertilizer on yield/ha of purple cabbage at harvest time

Here, F_0: control, F_1: vermicompost F_2: doses of NAA, F_3: ½ vermicompost and ½ doses of NPK

Effect of NAA

The yield of cabbage varied significantly due to the different levels of NAA after harvest. The treatment 40ppm NAA dose gave the maximum yield (25.39ton) and it was observed in N_2 treatment which was statistically identical with N_1 and N_3 treatments and the minimum yield was observed in N_0 treatment (15.41ton). At N_1 treatment yield was higher than N_0 but lower than N_2 (figure 8). At N_3 treatment (80 ppm) NAA gradually minimizes the cabbage yield than N_2 treatment. Higher concentration of plant growth regulators i.e. NAA proved less effective and were uneconomic in comparison to the control (Dharmender *et al*. 1996).

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 17). The maximum yield (36.80ton) was observed from F_3N_2 (½ vermicompost and ½ doses of NPK + 40ppm NAA) and the minimum yield/ha (14.64ton) was found from F_0N_0 (No nutrient sources and No NAA dose i.e. control condition) treatment. It was proved that the maximum yield of purple cabbage was found in the F_3N_2 combination.

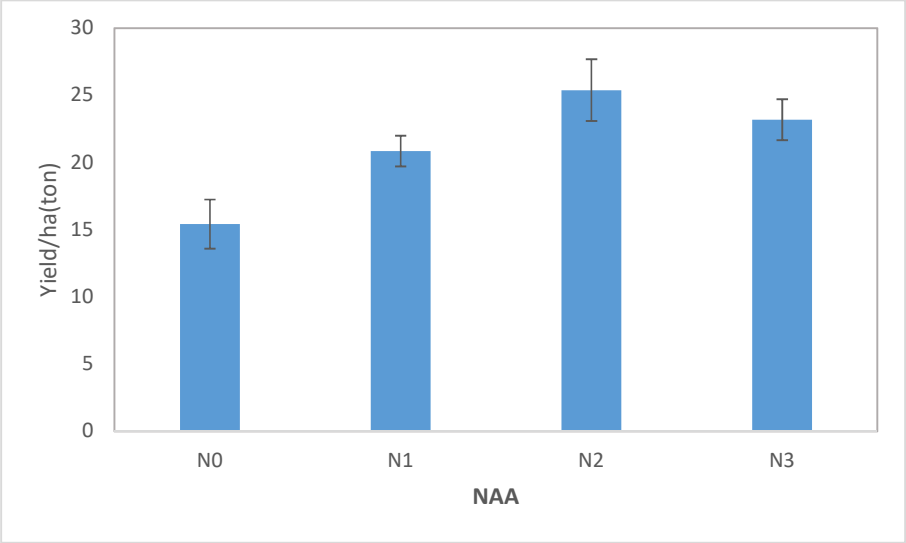


Figure 8: Effect of NAA on yield/ha of purple cabbage at harvest time

Here, N_0: 0 ppm NAA, N_1: 20 ppm NAA, N_2: 40 ppm NAA, N_3: 80 ppm NAA

Table 17: Combined effect of nutrient sources and NAA on dry weight, yield/plot and yield/ha of Purple cabbage

Treatment Combination	Dry Weight(g)	Yield/Plot(kg)	Yield/ha(ton)
F_0N_0	8.00±0.00	1.91±0.52g	14.64±1.82g
F_0N_1	8.00±0.00	5.14±0.39ef	17.83±1.35ef
F_0N_2	10.00±0.00	5.16±0.16ef	17.92±0.57ef
F_0N_3	8.00±0.00	6.28±0.61bf	21.82±2.11bf
F_1N_0	10.00±0.00	4.35±0.96f	15.11±3.33f
F_1N_1	12.00±0.00	5.19±0.47ef	18.03±1.62ef
F_1N_2	12.00±0.00	6.15±0.95cf	21.36±3.29cf
F_1N_3	12.00±0.00	5.27±0.91def	18.31±3.16def
F_2N_0	10.00±0.00	5.82±0.12cf	20.19±0.41cf
F_2N_1	8.00±0.00	6.50±0.30be	22.58±1.04be
F_2N_2	8.00±0.00	7.34±0.09bc	25.47±0.29bc
F_2N_3	12.00±0.00	7.05±0.66be	24.49±2.29be
F_3N_0	8.00±0.00	5.67±0.19be	19.70±0.64cf
F_3N_1	10.00±0.00	7.18±0.68bcd	24.92±2.39bcd
F_3N_2	12.00±0.00	10.60±0.51a	36.80±1.77a
F_3N_3	10.00±0.00	8.09±0.68b	28.10±2.37b
Significance level	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.

F_0: control, F_1: vermicompost F_2: doses of NAA, F_3: ½ vermicompost and ½ doses of NPK

N_0: 0 ppm NAA, N_1: 20 ppm NAA, N_2: 40 ppm NAA, N_3: 80 ppm NAA

4.17 Iron (Fe) content

Effect of nutrient sources

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 (1.64mg) while control treatment gave the minimum yield (1.29mg). The maximum Fe content was observed from treatment F_3 and the minimum was from F_0 treatment (Table 18). F_1 and F_2 treatments were given the maximum Fe content of control treatment and minimum than F_3 treatment (Appendix XXVIII).

Effect of NAA

The Fe content of cabbage varied significantly due to the different levels of NAA after harvest. The treatment 40ppm NAA dose gave the maximum Fe content (1.53mg) and it was observed in N_3 treatment which was statistically identical with N_0, N_1, and N_2 treatments and minimum Fe was observed in N_0 treatment (1.39mg) (Table 19).

The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of Fe content of Purple cabbage (Table 20). The maximum Fe content (1.75mg) was observed from F_3N_2 (½ vermicompost and ½ recommended dose of NPK + 40ppm NAA) which was statistically identical with F_3N_3 treatment (1.72mg) and the minimum Fe (1.25mg) was found from F_0N_0 (No nutrient sources and No NAA dose i.e. control condition) treatment which was statistically identical with F_0N_1 treatment (1.25mg). It was proved that the maximum Fe content of cabbage was found in the F_3N_2 combination.

4.18 Beta carotene content

Effect of nutrient sources

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 Fe content (1.64mg) while control treatment gave the minimum yield (1.29mg) (Table 18). The maximum Fe content was observed from treatment F_3 and the minimum was from F_0 treatment. F_1 and F_2 treatments were given the higher Fe content of control treatment and lower than F_3 treatment (Appendix XXIX). Vermicompost showed significant differences in plant height, unfolded leaves, head circumference, marketable yield, total yield, and nutrient content in cabbage (Reza *et al*. 2016)

Effect of NAA

The beta carotene content of cabbage varied significantly due to the different levels of NAA after harvest. 40ppm NAA dose gave the maximum beta carotene content (72.80µg) and it was observed in N_2 treatment and minimum beta carotene was observed in N_0 treatment (34.33µg) which was statistically identical with N_1 treatment (38.35µg) (Table 19).

The combined effect of different levels of vermicompost, NPK doses, and NAA showed statistically significant variation in terms of Beta carotene content of Purple cabbage (Table 19). The maximum beta carotene content (142.50µg) was observed from F_3N_2 (½ vermicompost and ½ recommended dose of NPK + 40ppm NAA) and the minimum beta carotene (10.10µg) was found from F_0N_0 (No nutrient sources and No NAA dose i.e. control condition) treatment. It was proved that the maximum beta carotene of cabbage was found in the F_3N_2 combination (table 20). The growth and physio-morphological characteristics, yield attributes, and yield were positively and significantly influenced by the application of vermicompost with a recommended dose of NPK and also cow dung compost with the recommended dose of NPK (Sajib *et al*. 2015).

Table 18: Effect of nutrient sources on Fe and Beta carotene content of Purple cabbage

Treatment	Iron(Fe)	Beta(β) Carotene
F_0	1.29±0.01d	17.90±1.82c
F_1	1.38±0.02c	38.43±3.57b
F_2	1.55±0.02b	52.38±3.21b
F_3	1.64±0.04a	99.61±12.66a
Significance level	***	***

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.

F_0: control, F_1: vermicompost F_2: doses of NPK, F_3: ½ vermicompost and ½ doses of NPK

Table 19: Effect of NAA on Fe and Beta carotene content of Purple cabbage

Treatment	Iron(Fe)	Beta(β) Carotene
N_0	1.40±0.04	34.33±5.54b
N_1	1.43±0.04	38.35±5.16b
N_2	1.50±0.05	72.80±13.18a
N_3	1.53±0.05	62.84±13.74ab
Significance level	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.

N_0: 0 ppm NAA, N_1: 20 ppm NAA, N_2: 40 ppm NAA, N_3: 80 ppm NAA

Table 20: Combined effect of nutrient sources and NAA on Fe and Beta carotene content of Purple cabbage

Treatment Combination	Iron(Fe)	Beta(β) Carotene
F_0N_0	1.25±0.03g	10.10±0.00
F_0N_1	1.29±0.007g	14.00±0.00
F_0N_2	1.30±0.01fg	23.20±0.00
F_0N_3	1.32±0.01efg	24.30±0.00
F_1N_0	1.32±0.01efg	23.30±0.00
F_1N_1	1.36±0.03efg	32.40±0.00
F_1N_2	1.39±0.05dg	55.00±0.00
F_1N_3	1.44±0.00cf	43.00±0.00
F_2N_0	1.46±0.02cde	48.60±0.00
F_2N_1	1.51±0.05bcd	47.00±0.00
F_2N_2	1.58±0.04bc	70.50±0.00
F_2N_3	1.63±0.01ab	43.40±0.00
F_3N_0	1.54±0.10bc	55.30±0.00
F_3N_1	1.55±0.11bc	60.00±0.00
F_3N_2	1.75±0.00a	142.50±0.00
F_3N_3	1.72±0.02a	140.65±0.00
Significance level	***	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.

F_0: control, F_1: vermicompost F_2: doses of NPK, F_3: ½ vermicompost and ½ doses of NPK

N_0: 0 ppm NAA, N_1: 20 ppm NAA, N_2: 40 ppm NAA, N_3: 80 ppm NAA

CHAPTER -V

SUMMARY AND CONCLUSION

The experiment entitled "Growth and yield of purple cabbage influenced by nutrient sources and NAA" was conducted in the experimental area of the horticultural farm, Department of Horticulture, Sher-e-Bangla Agricultural University (SAU) during the year 2018-19. The experimental crop used in the experiment was the red cabbage hybrid variety, Ruby King. The experiment was designed of two factors with three replications. Factor A- F_0: control; F_1: Vermicompost (10 ton/ha); F_2: N (180 kg/ha); P (66 kg/ha); K (75 kg/ha); F_3: ½ vermicompost and ½ doses of NPK; Factor B- N_0: 0 ppm; N_1: 20 ppm; N_2: 40 ppm; N_3: 80 ppm. There were 48 (16×3) treatment combinations.

Data were collected on different parameters like Plant height, Leaf number/plant, leaf length, leaf breadth, Days of 1st head formation, Canopy/plant, Whole weight of cabbage, Unfolded leaf number, Unfolded leaf weight, Head fresh weight, Head length, Head breadth, Root length, Stem diameter, Dry weight of purple cabbage, Yield per plot, Yield per hectare, Iron, Beta carotene content.

Results indicated that different parameters were significantly influenced by different levels of nutrient sources i.e. fertilizers (Vermicompost and NPK doses). It was found that the highest plant height (18.00, 22.75,31.33cm at 20, 40 and 60 DAT respectively), the maximum leaf number (13.42, 12.33, 11.67 at 30, 40 and 50 DAT respectively), canopy per plant (765.03, 1250.14 and 28.95.13cm2 at 20, 40 and 60 DAT respectively), the maximum whole weight of cabbage (891.32g) were recorded from F_3 treatment., the maximum head fresh weight (657.12g), the maximum root length (12.75cm), the maximum dry matter content (11.50g), the highest gross yield per plot (7.89 kg), the highest gross yield per ha (27.38 t/ha), the maximum iron (1.64mg), the maximum beta carotene (99.61µg) were also recorded from F_3 treatment. The minimum result was noticed in control treatment for all the parameter under studied.

Results indicated that different parameters were significantly influenced by different levels of Naphthalene Acetic Acid (NAA). It was found that the highest plant height (17.50, 21.92, 29.00cm at 20, 40, and 60 DAT respectively), the maximum leaf number (13.50, 12.50, 11.58 at 30, 40 and 50 DAT respectively), canopy per plant (806.93, 1227.38 and 2764.69cm2 at 20, 40 and 60 DAT respectively), the maximum whole weight of cabbage (831.41g) were recorded from N_2 treatment. Again the maximum head fresh weight (609.26g), the maximum dry matter content (10.50g), the highest gross yield per plot (7.31 kg), the highest gross yield per ha (25.39 t/ha), the maximum iron (1.53mg), the maximum beta carotene (72.80µg) were also recorded from N_2 treatment. The minimum result was noticed in control treatment for all the parameter under studied.

In terms of the combined effect of different levels of Fertilizers and NAA, the studied parameters were significantly influenced. The highest plant height (20.00, 25.67,35.67cm at 20, 40 and 60 DAT respectively), the maximum leaf number (15.33, 13.67, 12.67 at 30, 40 and 50 DAT respectively), the maximum leaf length (25.67 and 32.67cm at 40, 50 DAT respectively), the maximum leaf breadth (21.33 and 28.33cm at 40, 50 DAT respectively), the maximum canopy per plant (926.60, 1464.90 and 3496.40cm2 at 20, 40 and 60 DAT respectively), the maximum whole weight of cabbage (1100.60g) were recorded from F_3N_2 treatment. Again the maximum no. of unfolded leaves (10.33), the maximum unfolded leaf weight (302.93g), the maximum head fresh weight (883.07g), the maximum head length (10.57cm), the maximum head breadth or girth (11.29cm), the maximum root length (16.00cm), the maximum stem diameter (2.60cm) the maximum dry matter content (12g), the highest gross yield per plot (10.60 kg), the highest gross yield per ha (36.80 t/ha), the maximum iron (1.75mg), the maximum beta carotene (142.50µg) were also recorded from F_3N_2 treatment. In combined condition control treatment gave minimum result.

Conclusion and suggestions-

From the above discussion, it may be concluded that-

- In the experiment fertilizer effect at mixed condition (vermicompost + NPK) gave a better performance for growth and yield.
- Medium level NAA (40ppm) gave better performance.
- During the investigation, the treatment combination of F_3N_2 ((½ vermicompost and ½ doses of NPK + 40ppm NAA) was the best due to the highest gross yield.
- Considering the situation of the present experiment, further studies might be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.

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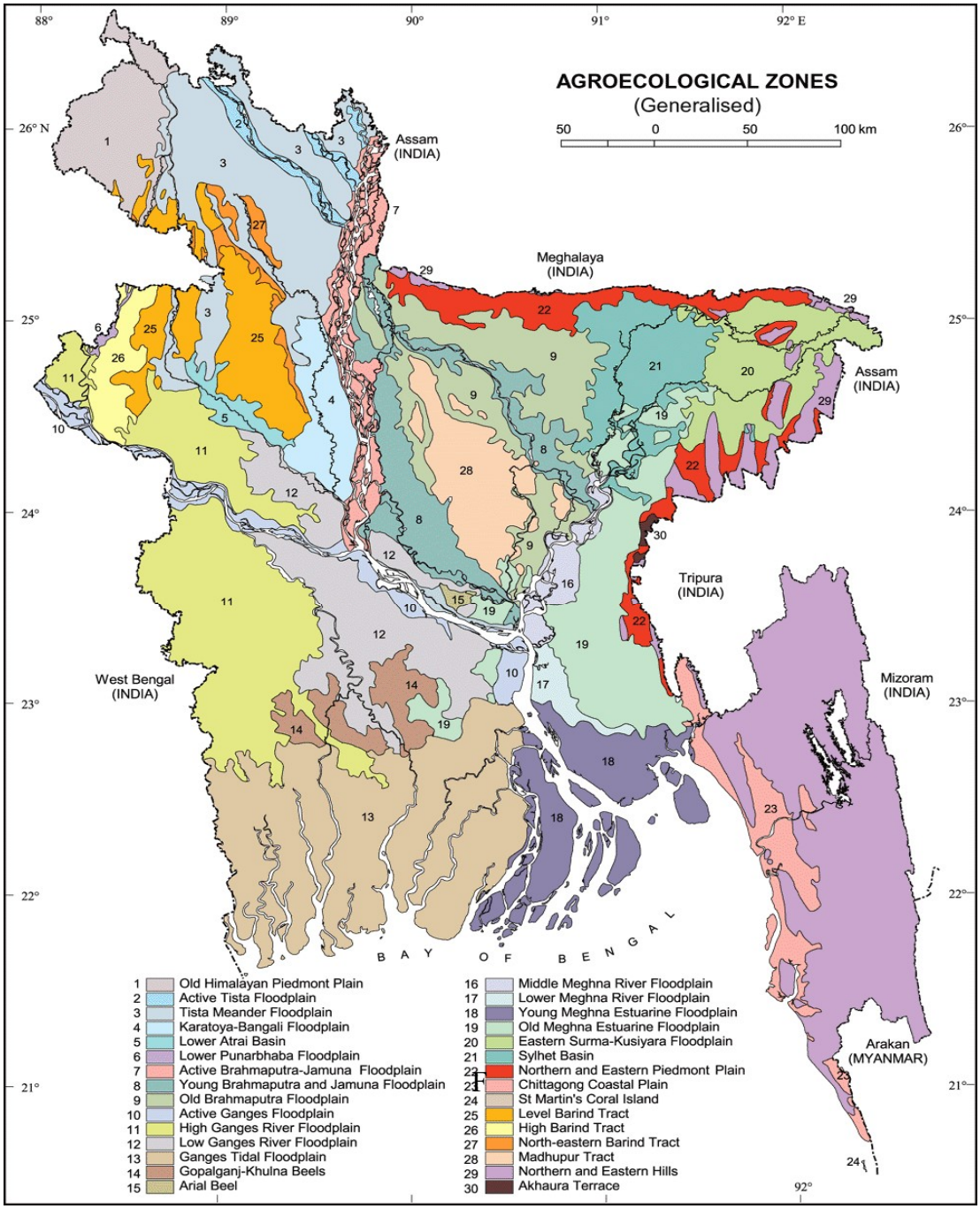
APPEDICES

Appendix I: Agro-Ecological Zone of Bangladesh showing the experimental location



Appendix II: Monthly records of air temperature, relative humidity, and rainfall during the period from October 2018 to February 2019.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2018	October	30.42	16.24	23.33	78.48	52.60
2018	November	28.60	8.52	18.56	56.75	14.40
2018	December	25.50	6.70	16.10	54.80	0.0
2019	January	20.42	11.70	17.75	46.20	0.0
2019	February	23.80	14.42	19.11	52.56	30

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III: Characteristics of soil from Sher-e-Bangla Agricultural University are analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka..

A. Morphological Characteristics of the experimental field

Morphological Features	**Characteristics**
Location	Sher-E-Bangla Agricultural University
ALZ	Madhupur Tract (28)
General Soil Type	Shallow Red Brown Terrace Soil
Land Type	high Land
Soil Series	Tejgoan *
Topography	Fairly Leveled
Flood Level	Above Flood Level
Drainage	Well Drained
Cropping Pattern	Fellow-Carrot
B. Physical and Chemical properties of initial soil	
Characteristics	Value
Particle size analysis	
% Sand	28
% Silt	42
% Clay	30
PH	5.9
Organic carbon (%)	0.08
Organic matter Total N	0.05
Available P	20.00

Source: Soil Resource Development Institute (SRDI)

Appendix IV: Analysis of variance of plant height at 20 DAT of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	39.229	3	13.076	12.177	0.000
Factor B: NAA	26.896	3	8.965	6.621	0.001
Interaction(A×B)	77.146	15	5.143	17.633	0.000

Appendix V: Analysis of variance of plant height at 40 DAT of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	90.563	3	30.188	17.382	0.000
Factor B: NAA	30.896	3	10.299	3.330	0.028
Interaction(A×B)	147.646	15	9.843	16.292	0.000

Appendix VI: Analysis of variance of plant height at 60 DAT of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	293.667	3	97.889	22.910	0.000
Factor B: NAA	67.500	3	22.500	2.390	0.081
Interaction(A×B)	431.000	15	28.733	18.147	0.000

Appendix VII: Analysis of variance of Leaf number/plant at 30 DAT of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	15.750	3	5.250	4.605	0.007
Factor B: NAA	23.750	3	7.917	8.261	0.000
Interaction(A×B)	50.583	15	3.372	7.038	0.000

Appendix VIII: Analysis of variance of Leaf number/plant at 40 DAT of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	7.167	3	2.389	2.661	0.060
Factor B: NAA	10.833	3	3.611	4.434	0.008
Interaction(A×B)	24.667	15	1.644	2.392	0.019

Appendix IX: Analysis of variance of Leaf number/plant at 50 DAT of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	10.083	3	3.361	6.384	0.001
Factor B: NAA	6.750	3	2.250	3.736	0.018
Interaction(A×B)	19.917	15	1.328	3.187	0.003

Appendix X: Analysis of variance of leaf length at 40 DAT of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	153.083	3	51.028	9.561	0.000
Factor B: NAA	100.417	3	33.472	5.123	0.004
Interaction(A×B)	283.250	15	18.883	5.773	0.000

Appendix XI: Analysis of variance of leaf length at 50 DAT of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	85.229	3	28.410	6.321	0.001
Factor B: NAA	20.563	3	6.854	1.149	0.340
Interaction(A×B)	174.312	15	11.621	3.422	0.002

Appendix XII: Analysis of variance of leaf breadth at 40 DAT of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	340.917	3	113.639	21.898	0.000
Factor B: NAA	87.417	3	29.139	2.661	0.060
Interaction(A×B)	455.917	15	30.394	8.582	0.000

Appendix XIII: Analysis of variance of leaf breadth at 50 DAT of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	276.729	3	92.243	15.130	.000
Factor B: NAA	97.063	3	32.354	3.178	.033
Interaction(A×B)	411.646	15	27.443	6.586	.000

Appendix XIV: Analysis of variance of plant canopy at 20 DAT of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	168369.576	3	56123.192	4.064	.012
Factor B: NAA	209702.696	3	69900.899	5.432	.003
Interaction(A×B)	503416.772	15	33561.118	3.941	.001

Appendix XV: Analysis of variance of plant canopy at 40 DAT of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	498658.099	3	166219.366	5.827	0.002
Factor B: NAA	137936.139	3	45978.713	1.252	0.303
Interaction(A×B)	999115.985	15	66607.732	2.824	0.007

Appendix XVI: Analysis of variance of plant canopy at 60 DAT of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	5975419.544	3	1991806.515	12.736	.000
Factor B: NAA	1344409.977	3	448136.659	1.713	.178
Interaction(A×B)	9317124.326	15	621141.622	5.616	.000

Appendix XVII: Analysis of variance of the whole weight of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	923204.852	3	307734.951	15.651	0.000
Factor B: NAA	422942.967	3	140980.989	4.543	0.007
Interaction(A×B)	1483512.040	15	98900.803	10.382	0.000

Appendix XVIII: Analysis of variance of unfolded leaf number of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	30.396	3	10.132	3.244	0.031
Factor B: NAA	7.729	3	2.576	.708	0.552
Interaction(A×B)	79.146	15	5.276	1.904	0.062

Appendix XIX: Analysis of variance of unfolded leaf weight of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	74186.182	3	24728.727	6.757	0.001
Factor B: NAA	1642.748	3	547.583	.103	0.958
Interaction(A×B)	88216.863	15	5881.124	1.280	0.270

Appendix XX: Analysis of variance of head fresh weight of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	536397.020	3	178799.007	10.118	0.000
Factor B: NAA	380533.943	3	126844.648	5.979	0.002
Interaction(A×B)	1086486.919	15	72432.461	10.190	0.000

Appendix XXI: Analysis of variance of head length of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	215.380	3	71.793	44.955	0.000
Factor B: NAA	18.750	3	6.250	1.030	0.388
Interaction(A×B)	251.865	15	16.791	15.905	0.000

Appendix XXII: Analysis of variance of the head breadth of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	80.672	3	26.891	12.538	0.000
Factor B: NAA	12.812	3	4.271	1.158	0.336
Interaction(A×B)	98.270	15	6.551	2.731	0.008

Appendix XXIII: Analysis of variance of root length of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	87.833	3	29.278	11.623	0.000
Factor B: NAA	31.167	3	10.389	2.729	0.055
Interaction(A×B)	136.000	15	9.067	4.630	0.000

Appendix XXIV: Analysis of variance of stem diameter of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	3.284	3	1.095	12.679	0.000
Factor B: NAA	0.515	3	.172	1.151	0.339
Interaction(A×B)	5.188	15	.346	5.840	0.000

Appendix XXV: Analysis of variance of the dry weight of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	56.250	3	18.750	11.000	0.000
Factor B: NAA	20.250	3	6.750	2.676	0.059
Interaction(A×B)	131.250	15	8.750	0.00	0.00

Appendix XXVI: Analysis of variance of yield/plot of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	77.260	3	25.753	10.121	0.000
Factor B: NAA	54.795	3	18.265	5.978	0.002
Interaction(A×B)	156.440	15	10.429	10.180	0.000

Appendix XXVII: Analysis of variance of yield/ha of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	931.289	3	310.430	10.115	0.000
Factor B: NAA	660.679	3	220.226	5.978	0.002
Interaction(A×B)	1886.512	15	125.767	10.186	0.000

Appendix XXVIII: Analysis of variance of Iron (Fe) content of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	0.902	3	.301	36.032	0.000
Factor B: NAA	0.138	3	.046	1.795	0.162
Interaction(A×B)	1.083	15	.072	12.435	0.000

Appendix XXIX: Analysis of variance of Beta carotene content of purple cabbage as influenced by different levels of fertilizer and NAA

Source of variance	Sum of square	df	Mean square	F-value	P-value
Factor A: Fertilizer	43369.884	3	14456.628	25.813	0.000
Factor B: NAA	12585.541	3	4195.180	3.330	0.028
Interaction(A×B)	68012.475	15	4534.165	0.00	0.00

Plate 1: Seedbed preparation

Plate 2: Germinated seedling in seedbed (10 days after sowing seed)

Plate 3: Applying fertilizer in the main field (basal dose)

Plate 4: Transplanting of seedling in main field (25days old age seedling)

Plate 5: Hormone (NAA) application (30 days old age seedling)

Plate 6: A unit plot (40DAT)

Plate 7: Data collection of purple cabbage (40 DAT)

Plate 8: Harvested Purple cabbage (74 DAT)

Plate 9: Sliced head for dry weight