# EFFECT OF MICRONUTRIENTS AND PLANT GROWTH REGULATORS ON MORPHO-PHYSIOLOGICAL CHARACTERS AND YIELD OF CAULIFLOWER


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## CERTIFICATE

This is to certify that the thesis entitled "**Effect Of Micronutrients and Plant Growth Regulatorson Morpho-Physiological and Yield of Cauliflower**"submitted to the Department of Agricultural Botany,Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master Of Science In Agricultural Botany**, embodies the results of a piece of bonafide research work carried out by**Ismat Ara Sharmin**, Registration No. **12-05103**under my supervision andguidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.


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*DEDICATED*

*TO*

*MY BELOVED PARENTS and GRANDPARENTS*

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The Author

# EFFECT OF MICRONUTRIENTS AND PLANT GROWTH REGULATORS ON MORPHO-PHYSIOLOGICAL CHARACTERS AND YIELD OF CAULIFLOWER


## ABSTRACT

The experiment was conducted during the period from 7 November 2017 to 22 February 2018 in the experimental field of Sher-e- Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka which laid out in a Randomized Complete Block Design (RCBD) with three replications. The research on 'Durga' variety of cauliflower with a view to know the effects of micronutrients and plant growth regulators on Morpho-physiological characters and yield of cauliflower. Micronutrients were applied before transplanting as basal application except control treated plot along with urea, TSP, MP, Furadan 5G for field preparation and plant growth regulators were applied at two different days after transplanting as foliar application including seven treatments of both micronutrients and plant growth regulators which were statistically analyzed combindly for accurately detected and compared. Treatments)- $T_o$: $B_o$, $Zn_o$, $H_{o\ (Control)}$; $T_1$: 5s kg/ha B; $T_2$= 5 kg/ha Zn; $T_3$: 5 kg/ha B + 5 kg/ha Zn; $T_4$: 5 kg/ha B + 5 kg/ha Zn + 50 ppm IAA; $T_5$: 5 kg/ha B + 5 kg/ha Zn + 50 ppm $GA_{3;}$ $T_6$: 5 kg/ha B + 5 kg/ha Zn + 50ppm IAA + 50 ppm $GA_3$. The maximum plant height, plant canopy, length of leaves at 40 DAT and chlorophyll content at 41 DAT were (45.32cm, 62.76cm, 28.21cm, 55.31 respectively) recorded from treatment $T_6$ but the maximum breadth (16.38cm) and num. of leaves (21.46) were found from treatment $T_4$ and $T_3$ respectively while the minimum was (31.93cm, 42.03cm, 21.45cm, 50.17 respectively) found from treatment $T_o$ except length of leaves that found from $T_{1.}$ At 55 DAT, the maximum plant height, plant canopy, length, breadth and number of leaves were (53.39cm, 71.73cm, 31.61cm, 18.3cm and 24.33 respectively) found from treatment $T_6$ while minimum were (35.13cm, 45.90cm, 23.32cm, 12.08cm, 15.13 respectively) found from control treatment $T_o$. After harvesting maximum stem length, curd diameter, weight of leaves, roots, fresh curd, marketable curd and fresh curd yield per bed, marketable curd yield ton per hectare and dry weight of leaves, roots, fresh curd were (15.11cm, 23.89cm, 754.06gm, 155.87gm, 1549.33gm, 2113gm, 30986.67gm/bed, 70.43ton/ha, 60.67gm, 28.02gm, 44.30gm respectively) resulted from treatment $T_6$ while only micronutrients treated on plants showed their higher resulted were (11.52cm, 20.15cm, 766.73gm, 58.16gm, 904.40gm, 1427.66gm, 18088gm/bed, 47.59ton/ha, 61.03gm, 16.93gm, 33.93gm respectively) found from treatment $T_3$ except stem length ($T_2$), chlorophyll content and leaf area index ($T_1$) and minimum were (8.32cm, 9.98cm, 327.78gm, 43.66gm, 430.80gm, 512.06gm, 8616gm/bed, 17.06ton/ha, 33.32gm, 22.19gm, 13.56gm respectively) resulted from control treatment $T_o$ except weight of roots and dry roots which were found from treatment $T_1$. Among those treatments, $T_4$ and $T_6$ treated plots were taken very few intended (43no.) days from transplanting to curd initiation and $T_{6,}$ combined treatment of micronutrient and plant growth regulators on plants induced superior result of Morpho-physiological characters and yield of cauliflower than only micronutrients treated plants or any other treatments.

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# CHAPTER I

# INTRODUCTION

Cauliflower (*Brassica oleraceae* var. *botrytis*) is healthiest warm sensitive cool seasonal vegetable. Latin words “Caulis” which means cabbage with flower called cauliflower, originated from northeast Mediterranean region before 2000 years ago. It is under Bracecaceae family and *Brassica* genus. The edible part of cauliflower is known as ‘Curd’ which is the pre-condition of inflorescence and used only as fry and ingredient of curry (FAO, 2011). It is a highly nutritious and delicious vegetable, rich in Vitamin A, C and minerals like calcium, iron and iodine (Haque, 1999). Cauliflower producing country are India, china, France, Italy Spain, United states of America. In Bangladesh, cauliflower cultivated all of district but commercially cultivated in Comilla, Bogra, Meherpur, Norshingdi, Jessore etc. The total vegetable production in Bangladesh is far below the requirement although consumption in Bangladesh is very low, only 32 g per person per day against the minimum recommended quantity of 200 g per day (FAO, 1986). The area was covered 48296-acre land and the total production was 268480 kg during the 2014-2015 with an average yield of 5559 kg/acre (BBS, 2015).

To get higher production and economical purpose, each crop need to maintain its fertilizer requirement and plant growth regulators application. Preliminary trials indicate possibility of yield increase of Cauliflower in Bangladesh with the use of bio-chemicals (Biswas and Mondal, 1988; Islam *et al*., 1994). Such as, In1987, reported by Mengel and Kibry, Although NPK is the main fertilizer but micronutrient such as Boron, Zinc, Molybdenum are played a vital role in the vegetative growth and production of cauliflower. The micro element not only play vital role in increasing the cauliflower production, but also regulate the physiological and metabolic process. Brassica crops has high Boron requirement and important for development of meristematic tissue cell division, nitrogen and carbohydrate metabolism, salt absorption and water elation in plant (Sharma, 2002). Boron applied as Borax as basal dose to relief from chlorotic and wither off diseases. Until the curds start developing, external symptoms of boron deficiency are not very apparent in most cases. The first sign of the appearance of small water soaked areas in the center of the curd. In later stages, it seriously affected the plants; the stem becomes hollow with water soaked tissue surrounding the walls of the cavity and causes hollow stem. Without Boron increases curd discoloration and deformation. In more advanced stages, pinkish or rusty-brown areas develop on the surface of the curd. Hence, it is known as brown rot or red rot. Datta (1963) further reported that boron and molybdenum increased the curd size and weight as well as ascorbic acid when applied together and molybdenum to avid whiptail. The main function of zinc in plant is of a metal activator of enzyme like dehydrogenase, proteinases and peptinases. And also Zinc is essential for carbon metabolism, plant nutrition, stomatal opening and to prevent abnormalities and malformation, synthesis of tryptophan, a precursor of IAA, which is essential for normal cell division and other metabolic process and helps in the formation of chlorophyll. Zinc has catalytic function and is required for the transformation of carbohydrate. Combination of Zn and B increases the maximum yield of cauliflower. The deficiency also causes interveinal chlorosis, reduced root growth blossoming and flowering. Similarly, shortened internodes and chlorotic areas of older leaves due to its deficiency were reported by Shanmugavlu (1989).

Then application of plant growth regulators (IAA, $GA_3$, BAP, Ancymidol, Ethopan, Chlormequal) are applied to 15 to 30 days after transplanting added new dimension for improvement, the function cell cycle, meristem function, apical dominance etc. are responsible for plant growth regulators. Auxin and cytokinin regulating each other synthesis signaling apical dominance. Application of Gibberellin ($GA_1$ and $GA_3$) promoted inflorescence stalk. First generation synthetic cytokinin BAP elicts plant growth, setting blossoms, development of responses, stimulating fruit richness (Siddqui *et al*., 2011). Plant height, curd formation and curd size of cauliflower can be increased with foliar application of plant growth regulators. $GA_3$ and IAA has a positive effect on curd formation and size of cauliflower (Sharma and Mishra, 1989). Exogenous application of $GA_3$ and urea either alone or in combination increased curd size as well as yield. Greatest plant height at curd formation (58.2 cm), curd diameter at maturity (26.8 cm) and increase in yield over the control (164%) were obtained with the 2 applications of $GA_3$ (Reddy, 1989). There are few work has been done to determine those effect on cauliflower. With the background stated above and keeping in view the growing importance of Boron, Zinc, IAA and $GA_3$ in cauliflower plant life cycle that my present study was undertaken to investigate the effect of micronutrients and plant growth regulators on Morpho-physiological characters and yield of cauliflower.

**OBJECTIVES:**

1. To observe the independent and together effect of micronutrients and plant growth regulators on Morpho-physiological characters of cauliflower.

2. To investigate the independent and together effect of micronutrients and plant growth regulators for ensuring the maximum yield of curd.

# CHAPTER II

# REVIEW OF LITERATURE

Many experiments have been carried out in developed country to investigate the effect of biochemical substances on the yield and quality of Bracecaceae family. Reports so far been made indicated a promising results on yield and quality of cauliflower and other crops due to the use of bio-chemical substances, Naphthalene acetic acid (NAA), Gibberellic acid ($GA_3$), Indole acetic acid (IAA) etc. (Voronova and Kozakov, 1983; Senthelhas *et al*. 1987; Tadzhiryan, 1990 and Tomar *et al*., 1991). In addition, it is generally accepted that a biochemical process is affected by a single chemical or a mixture of chemicals is not only different for between species but also for cultivars within the species and due to climatic regions (Hardy, 1979). Research findings regarding the effect of micronutrients such as boron, zinc etc. and growth regulators such as IAA, $GA_3$ etc. are applied at different growth stages of cauliflower on yield and yield components and curd size under Bangladesh condition is very limited. Considerable interest has been developed recently regarding the benefit from the use of plant growth regulators of cauliflower. $GA_3$ and IAA have been known to play a vital role in increasing the growth, yield and quality of cauliflower. In this chapter, an attempt has been made to review the research work done by different research workers on growth and yield of cauliflower. These results are of great importance in context to the present investigation. Therefore, literatures available from elsewhere on cauliflower and other crops on this aspect has been used in this chapter and has been presented here under appropriate headings.

2. 1 Effect of independent and together application of Boron and Zinc micro-elements on cauliflower and other crops
2. 2 Effect of independent and together application of IAA and $GA_3$ plant growth regulators on cauliflower and other crops.

## 2. 1 Effect of independent and together application of Boron and Zinc micro-elements on cauliflower and other crops

The role of micronutrients in regulation plant growth and yield is established. Zinc is an activator of enzyme involves in protein synthesis and has direct effect on the enzymatic cell wall development and RNA synthesis (Narayanamma *et al*., 2007).

Kumar *et al*. (2012) revealed that an experiment was conducted during rabi season of the year 2007-08. The observations were recorded on 11 characters eg. plant height (cm), number of leaves plant', fresh weight of leaves plant' (g), length of leaves (cm), width of leaves (cm), total weight of plant (kg), days taken to curd maturity, diameter of curd (cm), gross weight of curd (kg), net weight of curd and total yield (q $ha^{-1}$). Among all the treatment combinations treatment $T_{12}$ (Boron 20kg $ha^{-1}$ + sodium molybdate 2kg $ha^{-1}$) and $T_{14}$ (Boron 100ppm + molybdenum 50 ppm) gave best performance when application, respectively. Observation were recorded on total biomass production in cauliflower influenced by the application of different treatment of combination of boron. The maximum total biomass production (1.870 kg) recorded.

The highest vitamin C content was observed with boron applied and the minimum one at the highest Dose of B applied and its concomitant decrease with increase in the levels of B applied, may be explained in terms of the operation of the law of diminishing returns at higher dose of a given nutrient applied. such as curds were found more compact due to boron applied @1.5kgha$^{-1}$ and it increased compactness by 5.2 percent over boron applied @ 0.5 kg $ha^{-1}$ (Tisdale *et al*., 1995).

The higher B use efficiency at lower doses of nutrients applied, may be due to the greater competition among the plants for the applied nutrient (Kumar, 1992).

The maximum diameter of curd, volume of curd and average weight of curd per plot were recorded with foliar spray of zinc 0.5% concentration. The marked improvement in diameter and volume of curd by the application of zinc might be due to the improved physiological activities like photosynthesis during which food is manufactured by the plant, translocation of assimilates form leaves to curd and their storage in curd for which zinc was a responsible factor. These findings have been supported by Lal and Maurya (1981) in onion.

Shrihari *et al*. (1987) and Hazra *et al.* (1987) stated that zinc has involved in many metallo enzyme systems, regulatory functions and in auxin synthesis, which might have helped in enhancement in yield of okra. The non-significant result was obtained on total soluble solids (%) among different foliar sprays of zinc at 0.0, 0.5 and 1.0 % concentration, respectively.

Hussain *et al*. (2012) was conducted an experiment to determine the effects of N and B on the yield and hollow stem disorder of broccoli. Four levels of N as 0, 60, 120, 180 kg $ha^{-1}$ and four levels of B as 0, 0.5, 1.0 and 1.5 kg $ha^{-1}$ constituting sixteen treatments were applied in a split plot design with three replications. Applied N and B had significant impact on the yield and hollow stem disorder of broccoli. The highest curd yield of 15.14 t $ha^{-1}$ was obtained by 180 kg $ha^{-1}$ nitrogen. The incidence of hollow stem disorder was increased by increasing rate of N application and the highest value of hollow stem index of 1.38 was found with 180 kg N $ha^{-1}$. The curd yield of broccoli was significantly increased with boron application up to 1.0 kg $ha^{-1}$. This rate thus showed a remarkable impact on reduction of hollow stem disorder. A moderately high amount of B application (1.0 kg $ha^{-1}$) led to minimum incidence of hollow stem disorder, attaining considerably lowest value of hollow stem index of 1.0 as against the maximum value of 1.16 under no application of B. The interaction effect of N and B on yield and quality of broccoli was significant and the highest yield (16.68 t $ha^{-1}$) was recorded under 1180 kg N $ha^{-1}$and 1.0 kg B $ha^{-1}$.

Singh *et al.* (2015) reported that application of 120 kg N + 60 kg $P_2O_5$ + 40 kg $K_2O$ + 15 kg B $ha^{-1}$ gave maximum plant height $plant^{-1}$ (65.33 cm), number of leaves $plant^{-1}$ (18.26), length of longest leaf (52.99 cm), width of longest leaf (17.98 cm), spread of plant (55.53 cm) and stem diameter (4.47 cm), whereas in control was minimum pronounced plant height $plant^{-1}$ (58.66 cm), number of leaves $plant^{-1}$ (12.33), length longest leaf (42.70 cm) width of longest leaf (14.18 cm), spread of plant and stem diameter (3.04 cm) in broccoli. Similar, pattern on the curd diameter (13.69 cm), length of curd (16.33 cm), weight of curd $plant^{-1}$ (286.89 g), weight of sprout $plant^{-1}$ (126.89 g), weight of curd and sprout $plant^{-1}$ (0.390 kg) and total yield Curd + sprout (148.51 q $ha^{-1}$) was recorded with the application of 120 kg N + 60 kg $P_2O_5$ + 40 kg $K_2O$ + 15 kg B $ha^{-1}$ and minimum was under control treatment.

Bishnu *et al*. (2004) revealed that the effects of boron levels on cauliflower curd production. Six levels of boron (0 kg, 5 kg, 10 kg, 15 kg, 20 kg and 25 kg borax $ha^{-1}$) were tested. Fertilizers and manures were applied at the rate of 120:60:40 kg N: $P_2O_5$: $K_2O$ and 10 ton of compost per hectare in all the plots. The growth (plant height, leaf numbers, leaf length and fresh biomass production) was affected by the boron levels. The maximum plant height (42.05 cm) was observed when the crop was supplied with 25 kg borax ha$^{-1}$which was almost 13.95 percent higher than that of non-treated control crop. Maximum leaf numbers (12.73 plant$^{-1}$) and leaf length (38.91 cm) were observed when the crop was fertilized with 10 kg borax ha-1. The maximum biomass production (1.06 kg plant$^{-1}$) was obtained with the crop treated with 25 kg borax ha$^{-1}$. The curd size (diameter) was increased with increasing levels of borax up to 15 kg ha$^{-1}$. The maximum curd diameter (10.28 cm) was produced when the crop was treated with 25 kg borax ha$^{-1}$. Highly significant effect of boron level was observed on the curd production. The two years mean showed an increasing curd production trend with increasing levels of borax application. The maximum curd weight (10.9 t ha$^{-1}$) was observed when the crop was supplied with 25 kg borax ha$^{-1}$. However, non-significant differences on curd production were observed between 15 kg, 20 kg and 25 kg borax application ha$^{-1}$.

Varghese and Duraisami (2005) reported that the effect of B and Zn on the yield and nutrients uptake of cauliflower. The highest curd yield of 28.79 t ha$^{-1}$ was realized by the application of 1.0 kg B ha$^{-1}$ and 2.5 kg Zn ha$^{-1}$, which was 35.5 per cent over the yield recorded in control. The combined application of these nutrients beyond these levels tended to reduce the curd yield in cauliflower. Application of 1.0 kg B ha$^{-1}$ with 2.5 kg Zn ha$^{-1}$ was found to be better than individual application of various levels of B and Zn. Application of B increased the availability of all nutrients.

Alam (2007) observed that the growth, yield and other yield contributing characters of cabbage significantly affected by boron levels. The head weight and other growth and yield contributing parameters of cabbage increased up to 4.0 kg B ha$^{-1}$ ($B_4$) and decreased gradually with the increases of B level (>4.0 kg B ha$^{-1}$). The highest head weight (811.33g) was obtained with B4 followed by $B_3$ (748.67g) but both are statistically similar. The lowest head weight (384.33g) was found in $B_o$ but B7 (406.0g) is statistically similar with Bo.

Singh *et al.* (2009) observed that the effect of potassium and boron on yield, quality and uptake of nutrients in cauliflower at Bichpuri (Agra) during rabi season of 2005-07. Application of K and B significantly increased the curd and dry matter yield up to 90 kg $K_2O$ and 2 kg B $ha^{-1}$.

Dhakal *et al.* (2009) studied the effects of boron and phosphorus on the soil nutrient status, nutrient uptake by plant and yield of cauliflower (*Brassica oleraceae* var. *botrytis* L.) variety Snowball-16. Sixteen treatment combinations, including four levels of boron (0, 0.65, 1.3, 1.95 kg boron $ha^{-1}$ and four levels of phosphorus (0, 30, 60, 90 kg $P_2O_5$ $ha^{-1}$) were included. The highest curd yield, boron and phosphorus uptake by plant as well as available boron and phosphorus in soils after the crop harvest were obtained from the application of 1.3 kg boron with 60 kg $P_2O_5$ $ha^{-1}$. The boron uptake by plant was decreased by the application of more than 1.3 kg boron $ha^{-1}$ while the phosphorus uptake was increased with increased application of phosphorus up to 90 kg $P_20_5$ $ha^{-1}$. In conclusion, the combined application of 1.3 kg boron and 60 kg $P_2O_5$ $ha^{-1}$ was found to be the best for cauliflower production.

Kumar *et al.* (2010) revealed that the efficacy of various levels of boron and molybdenum as foliar and soil application on growth, yield and economics of cauliflower cv. Snowball K-1. Among the various treatments borax 20 $kgha^{-1}$ + sodium molybdate 2 kg $ha^{-1}$ as soil application in combination of recommended dose of NPK @ 120: 60: 60 kg ha $^{-1}$ ($T_{12}$) gave the maximum height of plant, length of leaf, width of leaf, total weight of plant, width of curd, average weight of curd and yield of curd, while foliar application of boron @ 100 ppm + molybdenum @ 50 ppm along with recommended dose of NPK @ 120: 60: 60 kg $ha^{-1}$ ($T_4$) gave highest growth and yield among all the foliar application treatments. The maximum net return (Rs.76865.00) and cost benefit ratio (3.15) was obtained under treatment $T_4$.

Singh *et al.* (2011) revealed that the 5 levels of Boron B, (1.0 kg $ha^{-1}$), $B_2$ (1.50 kg $ha^{-1}$), $B_3$ (2.0 kg $ha^{-1}$), $B_4$ (2.50 kg $ha^{-1}$) and $B_5$ (3.0 kg $ha^{-1}$), and 5 methods of its application, viz; M1 (broadcast in one dose), $M_2$ (broadcast in two doses), $M_3$ (band application in one installment), M4 (band application two installments) and $M_5$ (Foliar spray). Thus, there were altogether 26 treatment combinations along with control. Increasing levels of Boron from 1.0 kg $ha^{-1}$ to 2.50

kg ha$^{-1}$ showed linear increase in all the characters and was significantly superior to control, while the highest level i.e. 3.0 kg B ha$^{-1}$ could not prove superior to control. The maximum value of all the characters viz; plant height (63.98 cm), number of leaves (16.25). Effect of different levels of boron on cauliflower weight (1439.30 g), curd weight (758.70g), curd diameter (16.85 cm), curd depth (12.25 cm) and yield (446.20q ha$^{-1}$) were recorded in the plots receiving Boron @ 1.50 kg ha$^{-1}$. While the minimum viz; 48.12 cm, 2.88 cm, 906.25g, 387.45 g, 12.60cm, 8.10 cm and 215.23 q ha$^{-1}$ was noted in the control plots. Similarly, the effect of methods of application differed significantly in respect of all the characters. The maximum values of these characters were recorded with band application of Boron in two installments. The maximum values were recorded as plant height (58.38 cm), number of leaves (15.02), plant
weight (1277.88 g), curd weight (640.78 g), curd diameter (15.61 cm), curd depth (11.00 cm) and yield (375.97 q ha$^{-1}$) while the minimum values were recorded under control, respectively.
Sitapara *et al.* (2011) revealed that the two foliar sprays (at 15 and 30 DAT) of gibberellic acid @ 100ppm and boric acid at 0.2 percent were found better for growth attributes (viz, plant height, number of leaves, stem length, stem diameter, days taken for marketable curd etc.), yield attributes (viz, diameter, volume and weight of curd) and ultimately the early curd yield of cauliflower cultivar "Snowball-16".

Kamal Kant *et al*. (2013) results showed that treatments comprised of four basal doses of boron in form of borax (0, 5, 10 and 15 kg ha$^{-1}$) and Zinc in the form of zinc sulphate (0, 10, 20 and 30 kg ha$^{-1}$). There were 16 treatment combinations. The experiment was laid out in Randomized Block Design, replicated thrice. The hybrid used was Himani. All the experimental plots uniformly received 200 kg N, 100 kg $P_20_5$ and 80 kg $K_20$ ha$^{-1}$. The plant height, number of leaves plant$^{-1}$, biological yield, curd weight and marketable yield were found highest with combined soil application of 20 kg $ZnSO_4$ + 10 kg B ha$^{-1}$ which showed statistical equality with 30 kg $ZnSO_4$ + 10 kg B ha$^{-1}$.

Singh *et al*. (2013) results showed that the four levels of boron (5, 10, 15 and 20 Kg ha$^{-1}$) and three methods of boron application (Full through soil, Full through foliar spray and 1/2 through soil + 1/2 through foliar spray) in randomized block design having 12 treatment combinations on cauliflower (*Brassica oleraceae* var. *botrytis* L.) cv. Snowball. The results indicated that the all growth parameters (highest plant height, maximum diameter of stem, maximum spread of plant, minimum days of start of curd initiation and days to the completion of curd formation) were noted with $B_3M_2$ (15 kg $ha^{-1}$ boron through foliar spray) combination. Whereas, the treatment combination of $B_2M_3$ (10 kg $ha^{-1}$ boron by 1/2 through soil+1 /2 through foliar spray) was found as the best treatment combination in respect to maximum fresh weight of whole plant less root (742.25 q $ha^{-1}$) and highest yield of trimmed curd (310.83 q $ha^{-1}$) as compared to all other treatment combinations.

Kumar *et al.* (2013) showed that the effect of lime and boron in different combinations as soil, soil + foliar and foliar application on the growth dynamics and seed yield performance of snowball cauliflower PSBK-1, a field experiment was conducted during rabi season of 2008-09 under rainfed mid hill condition of Uttarakhand. It was found that application of lime and borax as basal @ 500 kg $ha^{-1}$ and 5.0 kg $ha^{-1}$ followed by foliar spray of boron @ 0.25% at 40, 60, 80 DAT was the best treatment for maximum number of leaves plant- ' (16.13), number of primary branches $plant^{-1}$ (12.53), seed yield $plant^{-1}$ (28.31g) and seed yield (7.96q $ha^{-1}$) whereas, application of lime and borax as basal @ 500 kg $ha^{-1}$ and 5.0 kg $ha^{-1}$ followed by foliar spray of boron @ 0.50% at 40, 60, 80 DAT was second superior treatment for highest plant height (92.06 cm), siliqua $plant^{-1}$ (1100.11), siliqua length (6.14 cm), seeds $siliqua^{-1}$ (20.34) and at par with seed yield $ha^{-1}$ (7.65 q).

Pillai (1967) reported that soil application of zinc at the rate of 11.22 kg $ha^{-1}$ increased yield of chilli by five per cent over control.

Balyan *et al*. (1994a) studied the effects of N (0, 60, 120 or 180 kg urea/ha) and Zn (0, 2.1, 4.2 or 6.3 kg $ZnSO_4$ $ha^{-1}$) on marketable yield, and the concentration and uptake of N and Zn by cauliflower cv. Snowball-16 in a field experiment during 1989-90 at Haryana Agricultural University, Hisar. Marketable yield increased with increasing rate of Zn to a maximum (198.57 q $ha^{-1}$) at a rate of 4.2 kg Zn $ha^{-1}$, then decreased. The highest concentrations of Zn in leaves and curds (48.82 and 50.02 ppm respectively) were observed at this Zn rate.

Mohapatra and Kibe (1971) reported that soil application of zinc as zinc sulphate (@ 22.40 kg $ha^{-1}$) increased the yield of tomato grown in Zn deficient soil.

Ashour (1973) showed that foliar spray of 100 ppm zinc sulphate after 45 days of sowing increased the yield of tomato.

Balyan and Singh (1994b) investigated the effects of N (0, 40, 80, 120 or 160 kg $ha^{-1}$), P (0 or 50 kg $P_2 0_5$ $ha^{-1}$) and Zn (0, 10, 20 or 30 kg $ZnS0_4$ $ha^{-1}$) on the yield of cauliflower cv. Snowball-16. In terms of yield, the best rate was Zn at 20 kg $ZnS0_4$ $ha^{-1}$.

Balyan and Singh (1994c) reported that Increasing Zn application up to 4.2 kg $ha^{-1}$ increased curd size index and marketable yield, and Zn application increased leaf curd ratio compared with no Zn.

Yagmur *et al*. (2002) reported in an experiment to assess the effect of Zn enriched and non-enriched 15:15:15 compound fertilizer on marrow cv. Sakis, yield result showed that Zn enriched 15:15:15 fertilizer applied at 50 kg $ha^{-1}$ significantly increased the yield, number and weight of fruit. In pea cv. Arkel the zinc in the form of zinc sulphate at 0.2 percent positively affected most of the yield contributing characters and pod yield.

Singh and Singh (2004a) conducted a cost-benefit analysis for cauliflower (cv. Snowball-16), supplied with foliar sprays of N (0.0, 0.5, 1.0 or 1.5%) and Zn (0. 10, 20 or 30 ppm) at 30 and 60 days after transplanting. The highest net return (52628.30 rupees $ha^{-1}$) and cost benefit ratio (1:2.803) were recorded for 1.0 % N + 30 ppm Zn, followed by 1.0 % N + 0 ppm Zn (51 447.87 rupees $ha^{-1}$ and 1:2.743).

Singh and Singh (2004b) investigated the effect of foliar application of N and Zn on the yield of cauliflower cv. Snowball-16. The treatments comprised combinations involving Nat 0, 0.5, 1.0 and 1.5% and Zn at 0, 10, 20 and 30 ppm. The maximum curd yield (238 q $ha^{-1}$) was obtained under N at 1% + Zn at 30 ppm. The highest cost benefit ratio (1:2.8) and net returns (Rs.5628.30/ha) were obtained with the treatment N at 1%+ Zn at 30 ppm.

Singh *et al*. (2014) results showed that doses of boron significantly affected the growth parameters, length of leaves and number of leaves plant$^{-1}$ at all stages of crop growth except 15 DAT. Application of boron at 2.0 kg ha$^{-1}$ through borax produced higher values of both growth parameters over 1.0 kg ha$^{-1}$ and control. Application of boron @ 2.0 kg ha$^{-1}$ being at par with 1.5 kg ha$^{-1}$ resulted in significantly higher chlorophyll content in leaves and leaf dry matter over rest of the doses. Plant survival percentage and days to 1st, 50% and 100% curd initiation remained unchanged due to different doses of boron. Application of boron at 2.0 kg ha" resulted in significantly highest circumference of curd (68.38 cm), fresh weight of curd (481.89 g), diameter of curd (10.48%) and yield of curd (214.47 q ha$^{-1}$) over rest of the doses. However, differences in circumference of curd, fresh weight of curd and yield of curd due to both the higher doses of boron were not significant.

Banerjee *et al*. (2015) results showed that the hollow stem of cauliflower can effectively be managed by both T4 and T5 i.e. application of Farm Yard Manure @ 7.5ton ha$^{-1}$ as basal and either application of Boric acid @ 0.3% or Liquid Boron @ 1.5 g L'" at 30 days after planting. The results of economic analysis reveal that highest net return as well as benefit cost ratio was also highest in $T_5$ followed by $T_4$.

Islam *et al*. (2015) results showed that the Early Green performed the best regarding head diameter (19.04 cm), yield plant$^{-1}$ (681.1 g) and total yield (27.24 t ha$^{-1}$). There was a significant and positive effect of boron application on the yield of broccoli. Control (without boron) treatment required highest days (48.92) for curd initiation but minimum days (61.75) for curd harvest. But 2 kg B ha$^{-1}$ treatment showed the opposite result. Result of maximum parameter revealed that, 2,0 kg B ha$^{-1}$ was found to be an optimum rate. The genotype Early Green yielded the highest (32.19 t ha$^{-1}$) when boron was applied @ 2 kg ha$^{-1}$.

Batabyal *et al.* (2015) found that Hot-calcium chloride ($CaCl_2$) extractable B in these soils varied from 0.33 to 0.78 mg kg$^{-1}$ and its content for deficiency to cauliflower was 0.48 mg kg$^{-1}$. Boron application significantly increased cauliflower yield, plant B concentration and uptake of B. The critical plant B concentrations for deficiency, sufficiency and toxicity varied with the growth stages and the values being 26, 31 and 48 mg kg$^{-1}$ at 50 days of growth and 17, 24 and 35.5 mg $kg^{-1}$ at harvest respectively. The study also recommends application of fertilizer B at the rate 0.9-4.5 kg $ha^{-1}$ for optimum B nutrition to cauliflower in Inceptisols of the Gangetic plains of India.

Moniruzzaman *et al.* (2007) revealed that a field experiment comprising six levels of boron (B) (0. 0.5, 1.0, 1.5, 2.0 and 2.5 kg $ha^{-1}$) and two levels of nitrogen (100 and 200 kg $ha^{-1}$) was conducted at the Agricultural Research Station, Raikhali, Rangamati Hill District during the winter (rabi) seasons of 2004-05 and 2005-06 to find out the suitable doses of B and N for higher yield and good quality head of broccoli. Boron application increased plant height, number of leaves $plant^{-1}$, length and width of the leaf, plant spread, main head weight and head yield both $plant^{-1}$ and hectare' significantly up to 1.5 kg $ha^{-1}$. Nitrogen application at higher dose (200 kg $ha^{-1}$) also significantly gave higher values for all growth and yield attributes as well as yield. Interaction effect of these nutrients was also found significant on all growth parameters except width of leaf, yield attributes and yield. Maximum yield $ha^{-1}$ was obtained at 2 kg B plus 200 kg N $ha^{-1}$ which was at par with 1.5kg B plus 200kg N $ha^{-1}$ and 1.5kg B plus 100 kg N $ha^{-1}$. The latter combination (1.5kg B $ha^{-1}$ + 100kg N $ha^{-1}$) gave the lowest hollow stem in broccoli during both years. Response curve indicates 1.59 kg B $ha^{-1}$ as optimum dose for this crop.

According to Govindan (1950) increased application of boron resulted in more and large tomato fruits and in higher Vitamin-C content in yellow and ripe fruits.

Rahman *et al*. (2014) results revealed that $T_1$ [4% N + (Mo) 50 mg $L^{-1}$ + (B) 80 mg $L^{-1}$] significantly increased the root length, leaf length, plant fresh weight, curd weight, circumference of curd and curd yield. Foliar spray 8% N gave the maximum values for plant aerial part, plant height, root fresh weight and dry weight which may be due to the excess of nitrogen while minimum values for all the studied attributes were examined in Control (Urea) 123.5 kg $ha^{-1}$. From these results it could be suggested and recommended that nitrogen in combination with micronutrients (Mo and B) are the most essential plant mineral nutrients in foliar fertilization method for growth and curd yield of cauliflower under poultry/chicken manure condition.

Boron is thus essential for plant growth and development as translocation of sugar and quality production depends on boron (Vasconcelos *et al*. 2011).

Boron is much required for cell division and development in the growth regions of the plant near the tips of shoots and roots. It also affects sugar transport and appears to be associated with some of the functions of calcium. Boron affects pollination and the development of viable seeds which in turn affect the normal development of fruit. Boron is taken up by plant roots as the neutral molecule $HB_4O_7^-$ and $BO_3^-$ (Gajendra singh *et al.* 2017).

Zinc is important for the formation and activity of chlorophyll and in the functioning of several enzymes and the growth hormone, Auxin. The form of zinc available to plants is the $Zn_2^+$ion. Zinc deficiency can occur on alkaline soils and sandy soils low in organic matter. (Gajendra singh *et al*. 2017).

Micro nutrients are as essential as macro nutrients because important growth processes depend on them. The basic role of boron lies in stabilizing certain constituent of cell wall and plasma membrane and enhancing membrane permeability, cell elongation, cell division, tissue differentiation and metabolism of nucleic acid, carbohydrate, protein, auxin and phenols. Application of boron to plant increased chlorophyll content (Sharma and Ramchndra, 1990).

The boron deficiency in soil caused by removal of boron by crops is not fully replenished by fertilizer applications. In contrast, high concentration and unbalance ratios of both, macro and micro nutrients lead to undesirable plant growth and development (Hall, 2002).

Ouda *et al.* (2008) reported that that plant growth is severely depressed by deficiency but high concentration of boron also reduces quality of crop. Foliar application of micronutrient to plant is the most effective and safest way. The foliage application of boron to get rid of B deficiency and to improve the quality and yield of vegetable has been suggested by many works.

Maximum curd size of cauliflower was recorded by Annon (1950) with the soil application of boron at 1 ppm.

Waring (1953) also recorded increase in curd size and found helpful in increasing curd weight with the application of boron.

Govindan (1952) observed the influence of B on carbohydrate balance in tomato crop and reported that increasing levels of B increased the reducing and non – reducing sugar content of tomato.

Besides this, Bussler (1962) reported significantly influenced root growth when capsicum plant was supplied with boron.

Pandey e*t al.* (1974) observed the influence of boron and zinc on cauliflower yield and quality. Development of boron toxicity symptoms on plants particularly at its high level were characterized by poor plant, stunted growth, small cup shaped lived with pinkish margin, impaired head formation, and brown colored heads. The level of available boron and zinc can significantly influence cauliflower yield an d quality.

Rajput and Singh (1974) reported that sugar content in cauliflower curds were increased with application of boron 1ppm.

Randhawa and Bhail (1974) observed that increased application of 20 kg borax proved to be toxic and decreased the yield of cultivar c.v. snowball-16. The application of borax @ 15 kg $ha^{-1}$ being remained at par with 10kg/ha and it increased the yield.  Among various interactions, the application of 120 kg N, 40 kg $P_2O_5$ along with 15 kg borax $ha^{-1}$ gave the maximum yield of cauliflower (163 q $ha^{-1}$) in comparison with all other treatments.

While Chowdhury (1969) reported highest acidity and sugar percentage with the application of boron @ 0.125 percent.

Hooda *et al*. (1984) obtained increased height of plant, number of branches, number of fruits and yields in tomato by zinc and boron application. The highest fruit yield was 529.88 q $ha^{-1}$ with 7.5 kg $ZnSO_4$ + 3.75 kg borax $ha^{-1}$ as compared to control (444.17 q $ha^{-1}$).

Shelp and Shattuck (1987) observed that different concentration of boron (0.025, 1.0, 2.5 and 12.5 mg) increased the optimum plant height, head yield and maximum fresh weight of curd in cauliflower CV. White tip.

Padma *et al.* (1989) reported that foliar sprays of 7.5 ppm Mo + 2.5 ppm B increased the number of flowers and powers and pod per plant and gave pod yield of 4.06-5.44 t $ha^{-1}$ compared with 3.01 t $ha^{-1}$ without trace elements in French beans.

Application of borax at 10 kg $ha^{-1}$ exhibited the highest yield (222.78 q $ha^{-1}$) as compared to control (163.63q $ha^{-1}$) in onion (Mishra *et al.*, 1990).

Favorable impact of curd initiation in cauliflower with the application in soil and foliar spray of boron has been reported. In this context. Rao *et al.* (1990) noted that foliar application of boron at 0.25% as borax resulted in early initiation of curd in cauliflower.

In another experiment conducted by Panigrahi *et al.* (1990), recorded increase in size of curd with application of boron at 0.2% as compared to control.

Singh (1991) investigated and found that maximum attainment of plant height and decrease in curd initiation period significantly with the application of 0.5% boron as compared to other concentrations.

Singh and Thakur (1991) reported that the boric acid, 0.005 to 0.001% (foliar spray) plus sodium molybdate at the rate of 1.5 to 2kg (soil application) is recommended to obtain higher curd yield of cauliflower.

Singh and Verma (1991) reported application of boron at 2kg ha$^{-1}$ alone or in combination with Zn or K, resulted in optimum plant growth, highest yield and income ha$^{-1}$ in tomato.

In an experiment Singh and Hoda (1992) reported that zinc sulphate at 15 kg ha$^{-1}$ and borax 7 kg ha$^{-1}$, significantly increased number of fruits plants$^{-1}$, fruit yield ha$^{-1}$ and TSS in muskmelon.

Foliar sprays of borax at 0.25 percent with $ZnSO_4$ at 0.25 percent, enhanced earliness and total yield in tomato (Agwah and Mohamood, 1994).

In an experiment, Medhi and Kakti (1994) carried out a research on Bhindi, cv. Prabhani Kranti and observed that micronutrient mixture in different grade significantly increased plant height number of leaves/plant, number of pods per plant and yield. The multiplex treatment resulted into highest cost-benefit ratio.

Sharma *et al.* (1994) reported increased yield with increasing B application up to 0.5mg per liter but decreased at higher rates in cauliflower.

Singh and Singh (1994) reported increased fruit set, total number of fruit plant$^{-1}$ and yield per plant by spraying 1.5 ppm of boron.

Sharma (1995) found that different levels of boron (0, 10, 20 and 30 kg borax ha$^{-1}$) increased the plant height, number of branches plant$^{-1}$, number of fruits per plant, fruit yield per plot and fruit yield ha$^{-1}$. Thereafter, all the above, parameters decreased with higher level of boron.

Combined application of Zn, Mn and B at 30 and 60 days after transplanting resulted into increased plant height, number of branches per plant, number of fruits per plant and fruit yield plant$^{-1}$ as compare to control in tomato (Bose and Tripathi, 1996).

In cauliflower cv. Pusa Snowball K-1, B was applied to the soil (1.5 kg ha$^{-1}$ as boric acid) or as foliar spray (1-4 spray of 0.125-4%) boric acid at 15 days interval from one week after transplanting. Foliar application of B was as good as soil application for increasing curd yield.

The highest curd yield (14.7 3 t $ha^{-1}$) was obtained with the 0.125% concentration while the lowest curd yield (6.87 t $ha^{-1}$) was obtained in the control. The curd yield declined at higher spray concentration due to the application of excess B (12.41 t $ha^{-1}$ with 4%). He also found foliar application of 3 sprays of 0.125% boric acid was optimum for high curd yield (23.46 t $ha^{-1}$), 76% higher than the control, low curd rot (5%) and high net returns per rupee invested Rs 4.74 (Kotur, 1998).

Chowdhury and Mukherjee (1999) reported that plant height, no. of leaves per plant, days taken to curd initiation, days taken to curd maturity, biological yield, average weight to curd and total marketable yield per hectare were significantly higher in 0.5 percent boron and 6ppm zinc concentration spray.  Besides, these, he also pointed out that days taken to curd initiation was advanced as a result of application of boron at 0.5% as foliar spray.

Batal *et at.* (1997) reported that on clay loam soil, increasing borax from 2.2 to 8.8 kg $ha^{-1}$ reduced hollow stem but had no effect on yield or curd mass. On the sandy loam soil, borax at 4.4 kg $ha^{-1}$ maximized yield and curd mass.

Significant improvement in weight of fruits by the borax application has been also reported by Dutta *et al.* (2000), in litchi and in mango cv. Himshagar.

Ghosh and Hasan (1997) reported that in cauliflower cv. Early Kunwari, treated with borax at the rate of 15 kg $ha^{-1}$, produce highest number of 27.2 leaves per plant the largest sized curd 1048g and highest yield (545 q $ha^{-1}$).

Sharma *et al.* (1999) reported that direct application of borax at 18 kg $ha^{-1}$ in soil or foliar application of 0.3 percent borax solution enhanced yield in cauliflowers, cabbage and kohl rabi by 16.1, 12.1 and 11.5 percent, respectively over control.

Singh *et al.* (2002) conducted an experiment with four levels of B applied at 0, 0.5, 1.0 and 2.0 kg $ha^{-1}$ (as borax) as band placed around each plant one week after transplanting. Soil application of B significantly produced higher marketable curd yield of cauliflower over control. Application of B up to 1.0 kg $ha^{-1}$ significantly increased the yields. Blackish curds appeared in the control.

Chattopadhyay and Mukhopadyay (2003) observed that in cauliflower cv dania, the highest borax rate resulted in the maximum curd yield (330.19 q $ha^{-1}$).

Prasad and Yadav (2003) reported that in cauliflower cv Snowball -16, four different conc. of boron and molybdenum (0, 0.1, 0.2 and 0.3 percent) were applied. Boron at 0.3% and molybdenum at 0.3% alone and in combination, were better than the other treatments in terms of growth (i.e. plant height, number of leaves per plant, root length, stem length, stem diameter and plant weight) and yield attributing characters (i.e. curd weight, and curd diameters) on the control.

In cabbage, significant increase in number of leaves after first spray of 0.5% borax was recorded by Sarma *et al.* (2003) and also found that among all the different treatments, the highest number of wrapper leaves and compactness of head was found by 0.5% borax treatment.

Singh (2003) reported that in cauliflower cv. Pusa synthetic, the treatments consisted of borax applied at various rates and methods, B significantly improved the vegetative growth and quality parameters of cauliflower. The maximum leaf stalk (6.78cm) was obtained with borax applied at 10kg $ha^{-1}$ as soil application. Borax applied at 5kg $ha^{-1}$ as soil application + 0.25% as foliar spray at 45 and 60 DAT, resulted in the highest number of leaves per plant. (17.4), leaf area (374.6$cm^2$), curd weight (510.0g), curd width (15.68cm), curd length (8.48cm), curd yield per plot (16.23kg), curd yield per hectare (140.86), net profit (51,203 rupees $ha^{-1}$) and benefit: cost ratio (4:20).

Sharma *et al.* (2005) documented that application of 0.5% borax recorded the highest yield and harvest index of cabbage.

he highest quality of protein and ascorbic acid content was found by 0.5% borax. While a significant improvement in the quality of radish root particularly ascorbic acid, reducing sugar and total sugar were obtained with the application of 0.1% borax as reported by Singh et al. (2006).

Montessori *et al.* (2012) revealed that the effects of foliar application of borax @ 0.1% solution on cabbage (*Brassica oleraceae* L. Var. *capitate*). The growth (plant height, leaf number, leaf length and fresh biomass production) was affected by the boron levels. The foliar spray was done twice at 25 and 50day s after transplanting (DAT). It showed significant increase in plant height, number of leaves, shoot weight, dry weight, root fresh weight and dry weight & yield. The head size (diameter) was increased with application of borax.

Acharya *et al.* (2015) carried out an experiment in order to study the effect of zinc and boron application on seeding transplanting multiplier onion $Co_5$ at different levels of both foliar and basal application. The experiment revealed that 10kg $ha^{-1}$ borax soil application showed significantly higher plant height, no. of leaves, Fresh weight of bulb yield, Ascorbic acid and TSS over control.

An experiment was carried out at the eastern University, Sri Lanka to study the effects of foliar application of boron, zinc and their combinations on growth and yield of tomato cv. Thilina. The result reveled that foliar application of B at 250 ppm resulted in higher plant height, No. of leaves, dry weight of total plant and fruits over control. (Harris & Mathuma, 2015).

Suganiya *et al.* (2015) conducted an experiment to investigate the effect of boron on flower and fruit setting and yield of ratoon crop of brinjal, at different levels of boron ($H_3BO_3$),0 ppm, 50 ppm, 100 ppm and 150 ppm. The result showed that foliar application of boron ($H_3BO_3$), at 150ppm increased percentage of fruit set (46%), no. of fruits $plant^{-1}$ (216%) and fresh weight of fruit $plant^{-1}$ (88%) than that of control, thus it resulted in higher yield per plant of ratoon crop of brinjal.

A pot experiment was carried out to evaluate the influence of foliar application of boron, copper and their combinations on the quality of tomato. The results showed that foliar application of boron, copper and their combinations significantly influenced yield and quality parameters such as acidity, ascorbic acid& TSS. The effect of B is greater than that of Cu. The application of B increased the fresh weight of fruits ($H_3BO_3$-350 ppm) and TSS ($H_3BO_3$-150ppm) significantly over control (Harris and Lavanya, 2016).

### 2. 2 Effect of independent and together application of IAA and $GA_3$ plant growth regulators on cauliflower and other crops

Anderson *et al.* (1948) also found the increased growth in cauliflower by the application of molybdenum. Combination of molybdenum with $GA_3$ and NAA was found to have significant effect due to synergistic action. These results are supported by the findings of El-Habbasha and Behairy (1977) in onion.

Brian *et al.* (1954) found that $GA_3$ failed to induce root growth in proportion in to vegetative growth. The views expressed by pirone (1958) that $GA_3$ applications created improper balance between top and root on account of under stress of the aerial growth on underground parts, causing temporary deficiency of nutrients, particularly nitrogen, seems to be the responsible cause in this case.

Jauhari *et al*. (1960) found that seedling treatment with $GA_3$ markedly reduced the transplanting shock and quite apparently influenced the early establishment of seedlings. Substantial increase in the number of leaves with $GA_3$ treatments is in conformity with the findings. This might have been due to invigoration of physiological process of plants and stimulatory effects with $GA_3$ to form new leaves at faster rates.

Denisova and Lupinovich (1962) found that $GA_3$ application brought about rapid vegetable growth, which subsequently helped in the early formation of large and compact heads. The probable cause of this may be increased nutrient transport from root to the aerial parts and increased rate of photosynthesis and accelerated transport of photosynthates by $GA_3$.

Chhonkar and Singh (1963) found that gibberellic acid has been used in different vegetables in recent years by many investigators and plant responses have been reported the potentiality of this plant growth regulator was ascertained for the furtherance of vegetable production, a number of methods of application have been tried on various vegetables.

Chauhan and Bordia (1971) carried out an investigation suing Drumhead variety of cabbage to assess the effects of Gibberellic acid ($GA_3$) at 5, 10, 15, 25, 50, 100 ppm, Beta-naphthoxyacetic acid (NAA) at 5, 10, 25, 50, 100 ppm and 2, 4- Dichlorophenoxy acetic acid (2, 4-D) at 0.25, 0.5, 1.0, 2.0, 2.5, ppm as pre-sowing seed treatment on the growth and yield of cabbage and mentioned that none of the treatments affected the height of the plants and the time taken for head formation. Maximum weight of head (1.72 kg) was obtained with 50 ppm $GA_3$ as against 0.81 kg under control.

Pandey and Sinha (1987) reported that photosynthetic area of the plant increased when treated with gibberellic acid naphthalene acetic acid.

Abdalla *et al.* (1980) conducted an experiment with the cauliflower varieties and the plants were treated with different concentration of IBA (5-40 ppm), $GA_3$ (10-80 ppm) or NAA (120-160 ppm) 4 weeks after twice more at fortnightly intervals. NAA at 160 ppm gave the highest yield with regard to curd diameter, weight and color. Similar results were obtained from plants treated with $GA_3$ at 80 ppm and NAA at 40 ppm.

Yabuta *et al.* (1981) reported that application of $GA_3$ had significantly increased marketable weight, petiole length, number of leaves and height many leafy vegetables the leaf area.

Islam (1985) conducted an experiment at the Bangladesh Agricultural University Farm, Mymensingh and applied various growth regulators (CCC, $GA_3$**,** NAA, and IBA) 30 days after transplanting of 32-day-old seedlings, CCC decreased the plant height, size of loose leaves, diameter of cabbage head and finally the yield. $GA_3$ increased the height of the plant, number of loose leaves per plant, size of leaf and finally the yield.

Patil *et al*. (1987) conducted an experiment in a field trial with the cultivar pride of India applied $GA_3$ and NAA each at 25, 50, 75 and 100 ppm one month after transplanting. Both the $GA_3$ and NAA increased the plant height significantly. The maximum plant height and head diameter and head weight were noticed with $GA_3$ at 50 ppm followed by NAA at 50 ppm Significant increase in number of outer and inner leaves were noticed with both $GA_3$ and NAA. Head formation and head maturity was 13 and 12 days earlier with 50 ppm $GA_3$. Maximum number of leaves and maximum yield (23.83 t $ha^{-1}$) were obtained with 50 ppm $GA_3$. At 30, 40, 50, 60 DAT and at harvest the tallest plant 27.1, 42.67, 53.12, 61.94 and 63.10 cm was found from applying (10 ppm IAA + 70 ppm $GA_3$) and the shortest plant 24.08, 37.23, 45.49, 50.07 and 52.38 cm was obtained from no hormone respectively.

$GA_3$ and IAA has a positive effect on curd formation and size of cauliflower (Sharma and Mishra, 1989).

Simao *et al.* (1958) reported that, application of $GA_3$ has increased the leaf size and number of lettuce.

Biswas and Mondal (1988) reported that protein, free amino acid of the seeds and mobilization index for protein in wheat increased from application of IAA with foliar spray. Plant height, curd formation and curd size of cauliflower can increase with foliar application of plant growth regulators.
Radwan (1955) reported the whole plant spray with $GA_3$ superior to pre-planting dip in tobacco.

Singh (1957) found maximum growth of tomato seedling when treated with 0.1 ppm NAA at the time of transplanting.

A study was conducted by Roy *et al.* (2010) at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh to study the effect of starter solution and $GA_3$ on growth and yield of cabbage. The two factor experiment consisted of four levels of starter solution, viz., 0, 1.0, 1.5 and 2.0% of urea, and four concentrations of $GA_3$, viz., 0, 25, 50 and 75ppm. The application of starter solution and different concentration of $GA_3$ influenced independently and also in combination on the growth and yield of cabbage. The highest yield (104.93 t $ha^{-1}$) was obtained from 1.5% starter solution which was significantly different from other solutions, and the lowest yield (66.86 t $ha^{-1}$) was recorded from the control. Significantly the highest yield (104.66 t $ha^{-1}$) was found from the treatment of 50 ppm $GA_3$, while the lowest yield (66.56 t $ha^{-1}$) was recorded from control. In case of combined effect, the highest yield of cabbage (121.33 t $ha^{-1}$) was obtained from the treatment combination of 1.5% starter solution + 50 ppm $GA_3$ followed by 1.5% starter solution + 75 ppm $GA_3$ (115.22 t $ha^{-1}$), while the lowest yield (57.11 t $ha^{-1}$) was produced by the control treatment. Economic analysis revealed that 1.5% starter solution + 50 ppm $GA_3$ treatment was the best treatment combination in respect of net return (Tk. 173775 $ha^{-1}$) with a benefit cost ratio of 3.52.

A universal response of marked elongation of stem by $GA_3$ was observed by Bukovac and Wittwer (1956) in a number of plants.

Apart from the effects on the morphological characters earlier flowering and fruiting was noted by Johnson (1958) in tomato with $GA_3$. Belik *et al.* (1961) reported increased yield of cabbage.

Mukheijee and Datta (1962) recorded improvement in quality of tomato and brinjal fruits by $GA_3$ application to plants.

Chhonkar and Singh (1959) recorded the increased yield of tomato by seedling treatment with growth substances.

Chhoonkar and Sing (1965) conducted an experiment in the Rabi season of 1962-63 with $GA_3$ at 5 and 10 ppm after two and three weeks of transplanting. They reported that 5 ppm $GA_3$ induced larger number of inner leaves in heads, earlier head formation by 16 days, increased head diameter, improved compactness and significantly increased the yield and quality of heads.

Chauhan and Singh (1970) found that 2 sprays of 15 ppm $GA_3$ at 3 weeks after cabbage transplanting increased earliness, yield and quality.

Badawi and Sahhar (1979) conducted at the experiment station of the Faculty of Agriculture, Cairo University, Egypt. They sprayed 0, 50, 100 and 200 ppm $GA_3$ and 10, 20 and 40 ppm IBA after 4 and 8 weeks of transplanting to determine the extent of simulating effect of different concentrations of $GA_3$ and IBA on cabbage.

Mishra and Singh (1986) found that all possible combinations of the levels of nitrogen (0, 0,5 and 1.0 per cent), boron (0, 0.1 and 0.2 percent) and $GA_3$ (0, 25 and 50 ppm) in the form of urea, boric acid and $GA_3$ were sprayed on snowball-16 cauliflower respectively. Results revealed that there was significant increase in growth characters namely plants heights, diameter of stem, number of leaves per plant, weight of plant, curd yield and nitrogen content in the stem and the leaves due to N, B and $GA_3$ applications. However, length of stem was increased only by $GA_3$ spray.

Muthoo *et al.* (1987) found that the foliar application of different concentration of $GA_3$**,** NAA and molybdenum increased the average fresh and dry weight of leaves. Curd and yield of cauliflower amongst the individual treatments. Gibberellic acid proved to be the best for the vegetative growth and molybdenum proved to be the best for growth of curd and yield of cauliflower (q $ha^{-1}$) followed by naphthalene acetic acid. The effect of treatment combination of 100 ppm $GA_3$, 120 ppm NAA and 0.2% molybdenum gave best result for all parameters of growth and yield.

De Leon and De Refols (1960) reported that the tomato treated with $GA_3$ resulted in higher no. of leaves.

Jauhari *et al.* (1960) noted increase in number of leaves in spinach with the use of $GA_3$.
Islam *et al.* (1993) 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, l00 ppm of both the NAA and $GA_3$ and applied in three different methods i.e. seedlings soaked for 12 hours, spraying at 15 and 30 days of 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 afterwards. They also added that two sprays with 50 ppm $GA_3$ was suitable both for higher yield and ascorbic acid content of cabbage.

Aditya and Fordham reported in (1995) that, field and glasshouse experiments were carried out to study the effects of cold exposure and $GA_3$ during early growth stages on the date of flowering of the tropical cauliflower cv. Early Patnai and the temperate cv. Lawyna. Flowering in cv. Early Patnai was advanced by approximately 25 days following vernalization (1 week at 10°C) of 3-week old plants. One week old plants failed to respond to this treatment suggesting a juvenile phase lasting up to about the 6-leaf stage in this cultivar.

Dharmender *et al*. (1996) studied that $GA_3$ alone or in combination with NAA (both at 25, 50 or 75 ppm) on the growth of cabbage (cv. Pride of India) was investigated in the field at Horticulture Farm S. K. A. College of Agriculture. Such as Rajasthan, India during rabi season (winter). The best growth (plant height, plant spread, number of leaves, leaf area and days to maturity) was observed following treatment with $GA_3$ at 50 ppm followed by NAA at 50 ppm. $GA_3$ at 75 ppm reduced the mean number of days required to start head formation. The highest chlorophyll content in outer leaves was observed following treatment with NAA at 50 ppm.

Vijoy *et al.* (2000) observed that 30day old cauliflower (cv. Pant Subhra) seedlings were transplanted into experimental plots and treated with 50 or 100 ppm $GA_3$, 5 or 10 ppm IBA, or 200 ppm NAA at 15 and 30 days of growth. The results clearly revealed that $GA_3$ producer the tallest plants, the largest curds and highest curd yields.

Anonymous (2003, 2004) was reported that, plant height was found significantly influenced by different levels of plant growth regulators. Plant height obtained maximum (113 cm) when the plants were treated with $GA_3$ 350 ppm which was statistically identical to $GA_3$ 300ppm (110cm) plant height.

Gibberellic acid is thus an important growth regulator that may have many uses to modify the growth, yield and yield contributing characters of plant (Rafeekher *et al.*, 2002).

The highest curd weight with leaf 2.05 kg was obtained when planting on 15 November and the lowest curd weight with leaf 1.34 kg was recorded when planting on 1 December. But highest curd weight with leaf 1.88 kg was observed by applying 10 ppm IAA + 70 ppm $GA_3$ which was closely followed 1.82 kg by applying 10 ppm IAA. The lowest curd weight with leaf 1.69 kg was found from control treatment or no hormone. And also the highest curd weight with leaf 2.52 kg was obtained from the treatment combination of month and treatment such as planting on 15 November x 10 ppm IAA + 70 ppm $GA_3$ whereas the lowest curd weight with leaf 1.01 kg was observed when planting on 1 December x no hormone. (Rahman *et al*., 2016)

The highest marketable yield per plant 1.20 kg was recorded by applying (10 ppm IAA + 70 ppm $GA_3$) which was closely followed 1.12 kg by applying l0ppm IAA and the lowest marketable yield per plant 0.94 kg was found from without hormone. so, the highest marketable yield 29.88 t $ha^{-1}$ was obtained from the treatment of 10 ppm IAA + 70 ppm $GA_3$ which was closely followed 27.89 t $ha^{-1}$ by giving 70 ppm $GA_3$. And the highest marketable yield 31.03 t ha-1was observed when planting on 15 November x 10 ppm IAA + 70 ppm $GA_3$, while the lowest marketable yield 21.75 t $ha^{-1}$was found when planting on 1 December x no hormone. (Rahman *et al*., 2016)

Harvesting at 30, 40, 50, 60 DAT the maximum number of leaves per plant (12.43, 15.91, 18.74, 23.40 and 24.13) was observed when planting on 15 November which was closely followed (11.95, 14.96, 18.06, 22.23 and 22.07) by planting on 1 November. Again, at the same DAT the minimum number of leaves per plant (11.21, 14.25, 16.27, 19.20 and 20.23) was found when planting on 1 December respectively. After harvesting the maximum number of leaves per plant (13.54, 15.68, 18.66, 23.06 and 23.66) was recorded where persist 10 ppm IAA + 70 ppm $GA_3$ which was followed (12.81, 15.35, 18.11, 22.31 and 22.84) only with 10 ppm IAA. Again, the minimum number of leaves per plant (9.9, 14.25, 16.38, 19.41 and 19.82) was found from without hormone for the same DAT, respectively at 30, 40, 50, 60 DAT and at
harvest the maximum number of leaves per plant (13.40, 17.02, 20.05, 25.38 and 26.42) was observed when planting on 15 November × 10 ppm IAA + 70 ppm $GA_3$ respectively, while the minimum number of leaves per plant (9.60, 13.25, 13.45, 15.29 and 17.68) was recorded from $P_3H_0$(planting at 1 December × no hormone respectively. (Rahman *et al.,* 2016)

$GA_3$ is a phytohormone that is needed in small quantities at low concentration to accelerate the plant growth and development. Gibberellins have been successfully employed by research workers for increasing growth, yield and for quality improvement of several vegetable crops.

Gibberellin requires the presence of an active or potentially active meristematic area for full expression of growth promoting effect (Brian *et al.*, 1962).

Paleg (1965) concluded that the mechanism of gibberellin action in the apex of a responsive plant results in increased protein synthesis, cell division, auxin production and cell expansion. Enhance growth activities to plant and stimulate stem elongation and increases dry weight and yield.

Avdovin and Kauntin (1961) reported that application of $GA_3$ @ 10 mg per liter increased the yield of lettuce by 20 -25%.

Bose and Hammer (1961) also noticed that foliar application of $GA_3$ resulted in increase in stem height, stem thickness and no. of leaves, in tomato.

Chhonkar and Singh (1964) reported that one or two spray of $GA_3$ at 5 ppm and 10 ppm two weeks after transplanting induced earlier head formation and longer compact head with more linear leaves in late drum head seedlings of cabbage.

Singh and Saimbhi (1968) conducted an experiment on response of Chinese cabbage to three plant growth regulators ($GA_3$, IBA and NAA) with three concentrations at 2nd and 4th week after transplanting. All the plant growth regulators were found to increase the number and size of leaves, fresh and dry weight as well as protein and ascorbic acid content of Chinese leaves as compared to control.

Badawi and Sahhar (1978) reported that application of $GA_3$ @50 ppm four week after transplanting increased the head weight by 20% over control.

Kaushik *et al*. (1974) carried out an experiment with the application of $GA_3$ at 1, 10 or 100mg/l on tomato plants at $2^{nd}$ leaf stage and then at weekly intervals until $5^{th}$ leaf stage. They reported that $GA_3$ increased the number and weight of fruits per plant at higher concentration.

Suryanarayan and Rao (1981) reported that okra treated with $GA_3$ (50 ppm) which gave the yield of 64.42 q $ha^{-1}$ compared with 57.61q $ha^{-1}$ in control.

Saleh and Abdul (1980) conducted an experiment with $GA_3$ (25 and 50ppm), which were applied 3 times in June to early July. They reported that $GA_3$ stimulated plant growth and increased the total yield compared to control.

Gorgiev and Vetenovska (1987) reported that $GA_3$ application in general, increased protein content in poppy.

In another experiment, Rattan *et al.* (1987) compared different combination of $GA_3$ and IAA concentrations for seed treatment or whole plant spray on okra, and observed significant effect on number of days to flower, number of pods $plant^{-1}$, pod length and green pod yield per plant. The highest number of pods and pod yield per plant were obtained by treating the seed with 50 ppm $GA_3$ + 100 IAA ppm as sprays.

Mohan & Sinha (1988) in an experiment with application of $GA_3$ on tomato plant found best treatment (5ppm) with regard to yield, ascorbic acid, chlorophyll and nitrate content.

El-Quensi *et al.* (1989) conducted a greenhouse experiment on spinach and obtained the highest plant height (39cm) with 50 ppm $GA_3$ spray.

Reddy (1989) conducted a field experiment on cauliflower and reported the greatest leaf length and breadth of curd were obtained with two application of urea & one application of $GA_3$. While greatest plant height at curd formation stage and curd diameter at maturity and increase in yield were obtained with two applications of gibberellins.

Abdel (1996) applied 16 treatments representing all possible combinations of four N rates and four $GA_3$ concentration viz. 0, 30, 60 and 90 ppm foliar spray 5 and 8 week after sowing in carrots. He observed increase in fresh and dry weight of root, root length and diameter and total yield increases in $GA_3$ concentration, except no significant differences between 60and 90ppm applications. Fresh and total yield both increased with increasing concentration of $GA_3$ with no significant difference between 60 and 90 ppm.

Belakbir *et al.* (1998) tested the effectiveness of different bio-regulators in enhancing bell pepper yield and quality of SCRI, Scotland. They reported that $GA_3$ increased ascorbic acid content.

Paliwal *et al*. (1999) conducted an experiment on "Pusa Sawani" with $GA_3$ and NAA spread alone as well as in combination at 20 and 40 days after sowing. The results revealed that foliar application of $GA_3$ exhibited beneficial and significant effect with increasing $GA_3$ levels. The response was linear and maximum with 75 ppm $GA_3$ spray, which was significantly superior to other treatments and control.

Vijayaraghavan (1999) concluded an experiment on Bhindi and conducted that, $GA_3$ at 50 ppm recorded the highest yield of 15.7t $ha^{-1}$ followed by $GA_3$ 75 ppm with 14.8t/ha. The control yield recorded was 8.07 t $ha^{-1}$.

Arora *et al.* (2000) conducted a laboratory study to evaluate the effect of $GA_3$ treatment on the shelf life of chili cv. Pusa Jawala. Chili fruits were treated with 0, 50, 100 and 200 ppm $GA_3$ for 10 minutes and air dried before packing. The fruits treated with 200 ppm $GA_3$ exhibited the lowest PCW (physiological loss in weight) 20.8% on the $25^{th}$ day of storage, compared with 33.4% in the control.

Davis and Nunez (2000) reported that foliar application of $GA_3$ increases the shoot system such as plant height, number of leaves, lateral buds, number of branches and numbers of flowers in carrot.

Kumar and Ray (2000) carried out an experiment on cauliflower. The plants were spread with $GA_3$, NAA and IBA @ 100 and 200 ppm. They reported that $GA_3$ @100 ppm produced tallest plants, the largest curds and highest curd yields. They also observed that the cauliflower cv. Plant shubhra treated with $GA_3$ 50mg $liter^{-1}$ and 100 mg $liter^{-1}$ concentration recorded greater curd circumference and significant increase in curd yield.

Yadav *et al.* (2000) carried out an experiment on cabbage cv. Golden Acre which is with $GA_3$ @ 50, 100 & 150 ppm once (30 DAT) and twice (30 & 60 DAT). They found that double spray of $GA_3$ @150 ppm significantly increased height and plant spread over control. While double spray of $GA_3$ @100 ppm significantly increased the number of open leaves and yield as compared to control.

Singh and Rajodiya (2001) reported higher root girth fresh weight of root with yields of 497.26 q $ha^{-1}$ when treated by $GA_3$ over control in case of radish.

Tiwari *et al.* (2003) reported that application of $GA_3$ @ 25 ppm after transplanting significantly gave higher TSS.

Singh *et al.* (2002) reported in onion crop, that plant treated with $GA_3$ @10 ppm recorded the greatest plant height (44.40cm), number of leaves per plant and bulb yield (120.69q $ha^{-1}$).

Singh *et al.* (2003) carried out an experiment on "knol khol" and concluded that the foliar application of GA3 @ 75 ppm was more beneficial to obtain higher yield.

Balakrishnamorthy and Balasubramanian (2005) recorded highest fruit length, fruit girth and fruit weight with the treatment of $GA_3$ @100ppm in okra.

Kumar and Sen (2005) reported that the application of $GA_3$ 50ppm had a significant effect on fruit weight, length, number of fruits and yield per plant in case of tomato.

Kumar *et al.* (2005) observed that postharvest application of $GA_3$ @600ppm in tomato recorded the lowest physiological weight loss up to 12 days of storage.

An experiment was conducted to study the effect of plant growth regulators on growth, yield and quality of cabbage cv. "Golden acre" Spraying of $GA_3$ @ 5mg $l^{-1}$ found to be most effective treatment to induce earlier head formation as well as increased plant height, plant spreads, stalk length, head diameter, fresh and dry weight of head and yield per hectare. Although from the economic point of view NAA @ 25mg $l^{-1}$ was found to more profitable as compared to rest of the treatments, but net returns over control is highest in $GA_3$ 5mg $l^{-1}$ foliar. So it may be suggested to spray $GA_3$ 5ppm after 30days of planting in cabbage may be profitable. (Makwana, 2005)

An experiment was carried out at Regional Horticultural Research, Navsari Agricultural University, Navasari, during rabi season of the year 2004. The result revealed that foliar application of gibberellic acid (125ppm) and boron (0.2%) recorded higher plant height, number of non-wrapping leaves per plant, days taken to head formation and its maturity, head diameter, fresh weight of shoot and fresh weight oh head, volume of head, yield (q/ha) and total soluble solids as compared to control. (Singh, 2005).

Bokade *et al.* (2006) reported that spraying $GA_3$ @ 50 ppm twice at 50% flowering and fruit developed stage increased plant height in tomato.

Awan and Alizai (1989) reported significant increase in plant height, number of tiller(s) plant$^{-1}$, number of grain panicle$^{-1}$, grain yield and protein content of grain by foliar application of l00ppm $GA_3$ or IAA at panicle emergence stage and also significant decrease in sterility percent on rice.

In Pea, Mishriky (1990) found that protein content was increased when 50 ppm $GA_3$ was applied 30 days after sowing. The foregoing discussion indicates that growth regulators such as $GA_3$ and IAA could increase the grain yield as well as protein content of wheat. The effectively of such growth regulators may, however, be pronounced due to timing of application in terms of growth stage of wheat.

Gonzalez *et al.* (2007), has conducted an experiment to know the effect of gibberellic acid application on growth of cauliflower (Var. *botrytis*.), and reported the favorable effect of gibberellic acid upon growth attributes.

The effect of $GA_3$ and NAA (both at 25, 50, 75 or 100 ppm) on the yield and yield parameters of cabbage (cv Pride of India) was investigated by Dhengle and Bhosale (2008) in the field at Department of Horticulture, college of agriculture, Parbhani. The highest yield was obtained with $GA_3$ at 50 ppm (332.01q $ha^{-1}$).

Dhengle *et al.* (2008) reported that cabbage showed a quick growth, early head formation and higher yield, when treated with plant growth regulators especially $GA_3$ and NAA.
Chauhan *et al.* (2009) reported that application of $GA_3$ increased the ascorbic content in cabbage.

The effect of gibberellic acid on broccoli was studied by Wang and Yang (2008) and reported that inflorescence differentiation and curd yield was increased, but the vitamin C of curd was decreased.

A field experiment was conducted at the Gwalior (Madhya Pradesh) by Jordan *et al.* (2009) to study the effect of gibberellic acid, IBA and NAA as foliar spray of cauliflower. The result indicated that growth characters like plant height, diameter of the stem, spread of the plant and number of leaves per plant were increased significantly under different treatments. Yield attributing characters viz., diameter of curd, weight of curd per plant, weight of the head per plant, length of head, yield and dry weight of curd per 100g of fresh weight were also increased significantly with different treatment. Among growth regulator, $GA_3$ (150 ppm) was most promising in effect followed by NAA & IBA.

Studies on influence of $GA_3$, NAA and CCC at three different Concentration on different growth parameters of cabbage (cv. Pride of India) were studied by Lendve *et al.* (2010) and found that application of $GA_3$, 50 ppm was found significantly superior over most of the treatments in terms of numbers of leaves, plant-spread, fresh and dry weight of plant, fresh weight of root. However, $GA_3$, 75 ppm gave better result for days required for head initiation and head maturity.

Manjit *et al.* (2011) conducted a yield experiment on sprouting broccoli cultivar, Palam samridhi upon effect of different levels of $GA_3$ 20, 40, 60, 80,100ppm. On growth, yield & quality of sprouting broccoli, & reported that Vitamin C & yield increased significantly in respect to control, but Vitamin C content decreased significantly on concentration of $GA_3$ more than 20ppm, while the yield noticed an increase up to concentration of 60ppm.

A study was conducted by Roy *et al.* (2011) at the Horticulture Farm Bangladesh Agricultural University, Mymensingh to study the effect of starter solution and $GA_3$ on growth & yield of cabbage. The two factors experiment consisted of four level of starter solution, viz. 0, 1.0, 1.5 and 2.0% of urea and four concentrations of $GA_3$, viz. 0, 25, 50 and 75 ppm. Significantly the highest yield (104.66 t $ha^{-1}$ was found from the treatment of 50ppm $Ga_3$, while the lowest yield (66.56 t $ha^{-1}$ was recorded from control. In care of combined effect, the highest yield of cabbage (121.33 t $ha^{-1}$) was obtained from the treatment combination of 1.5% starter solution + 50ppm $GA_3$ followed by 1.5% starter solution + 75ppm $GA_3$ (115.22 t $ha^{-1}$) while the lowest yield (57.11 t $ha^{-1}$) was produced by control treatment.

Kumar *et al.* (2012) conducted a study with an aim of find out the influence of foliar mineral nutrients and $GA_3$ spray upon broccoli and observed that $GA_3$ (0.01%) had resulted in higher TSS, total sugar, Ascorbic Acid & soluble protein over control as well as proved successful in lowering the phenol content significantly.

Kumar *et al.* (2012) reported that $GA_3$ (0.01%) also had significantly higher value over control in respect of plant spread, stalk length, No. of leaves, Days to 50% head initiation & Days to 50% head maturity, Head width, Head volume & yield (q $ha^{-1}$).

Desai *et al*. (2012) conducted an experiment on tomato variety GT-3 (Gujarat tomato-3) at JAU, Junagarh, India. They found maximum fruit length (7.57 cm) with $GA_3$ @75 ppm.

Ayyub *et al.* (2013) found that exogenous application of $GA_3$ hastens the vegetative and reproductive growth of okra. The foliar application of $GA_3$ (100mg $L^{-1}$) was quite effective in boosting the stem elongation and no. of leaves.

Thapa *et al.* (2013) evaluated the role of $GA_3$ and NAA on growth, yield and quality attributing characters of broccoli and reported an increasing trend in yield by the foliar application of $GA_3$.

An experiment was conducted by Chaurasiy *et al*. (2014) at Babasaheb Bhimrao Ambedkar University, Lucknow, U.P. to study the response of cabbage cv. Pride of India to foliar application of PGRs namely $GA_3$ and NAA with different concentrations. The experiment revealed that $GA_3$ @60ppm significantly increased the plant height (33.26cm), number of leaves (21.48), plant spread (55.59), stem diameter (3.05cm), plant weight (2.44 kg), head weight (1.73kg), head diameter (18.88cm), as well as head yield (51.26 t $ha^{-1}$) than the other treatments & control.

Kazemi *et al.* (2014) investigated the effect of 2 levels of $GA_3$ ($10^{-4}$ and $10^{-8}$ mm) and 2 levels of potassium nitrate (6 to 8 mm) spray at, University Karaj, Iran. With regard to fruit quality, the application of $GA_3$ at $10^{-8}$ mm and potassium nitrate at 8 mm increased TSS content. They concluded that $GA_3$ was suitable for increasing vegetative growth and reproductive characteristics of tomato.

Kumar *et al.* (2014) conducted an experiment on tomato crop at Shiats, Allahabad, and U.P. The experiment consisted of the tomato variety "Golden" and five levels of $GA_3$ i.e. 10, 20, 30, 40 and 50 ppm the objective was to determine the effects of $GA_3$ on growth, yield and quality of tomato. The reported that maximum plant height, number of leaves, number of fruits, fresh fruit weight, ascorbic acid and TSS, resulted with the application of $GA_3$ @50ppm.

Netam *et al.* (2014) observed the effect of PGR in brinjal Var. Brinjal-3112 at Shiats and U.P. They observed highest number of leaves, plant height, fresh and dry weight of fruit with $GA_3$ @50ppm.

Vandana *et al.* (2014) conducted an experiment on sweet pepper cultivar "Indra" under green house and confirmed the maximum plant height (30.15cm) with $GA_3$ 50 ppm. Maximum yield $plant^{-1}$ (1.84kg) and yield $ha^{-1}$ (244.65q $ha^{-1}$) recorded with $GA_3$ @50 ppm.

Akand *et al.* (2015) conducted an experiment on tomato crop at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The experiment consisted of three concentrations of $GA_3$ i.e. 75

ppm, 100 ppm and 125 ppm. Among the concentrations of $GA_3$, they found highest yield (92.99 t $ha^{-1}$) with $GA_3$ @125 ppm whereas the $G_0$ (no $GA_3$) gave lowest yield (60.46 t $ha^{-1}$).

Rahman *et al.* (2015) and Sanyal *et al.* (1995) reported that root soaking with 50 ppm GA3 has been shown to significantly increase the number of flowers, fruits and yield in tomato.

Reza *et al.* (2015) conducted an experiment to find out the influence of $GA_3$ at 4 levels of concentrations, 0, 25, 50 & 75 ppm on growth, yield and yield attributing characters of broccoli and reported that maximum height (31.5 cm), number of leaves (16.6), main curd length (21.3 cm), main curd diameter (19.3cm), main curd weight (668.0g $plant^{-1}$) and yield (24 t $ha^{-1}$) was found with the application of 50ppm $GA_3$ while the minimum value was recorded with control. It was also found that application of more than 50 ppm $GA_3$ reduced the yield of broccoli.

Kar *et al.* (2016) reported that significantly highest number of fruit per plant was obtained with 120 kg $ha^{-1}$ $K_2O$ along with spraying of 50 ppm $GA_3$. He reported that there was an increase in 15% of fruit yield with application of $GA_3$ 50 ppm, in case of chili.

# CHAPTER III

# MATERIALS AND METHODES

The methods employed during the course of investigation and materials utilized have great significance in the research on the cauliflower field experiment entitled “Effects of micronutrients and plant growth regulators on Morpho-physiological characters and yield of cauliflower.” The details of material used and techniques employed in carrying out the investigation were described in this chapter.

## 3. 1 Experimental Site

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site in 23° 74' N latitude and 90° 35' E longitude with an elevation of 8.2 meter from sea level (Anonymous, 1989).

### 3. 1. 1 Experimental Period

The experiment was carried out during Rabi season from November 2017 to February 2018.

### 3. 1. 2 Climate

The climate of the experimental site is subtropical, characterized by heavy rainfall during the months from April to September (Kharif season) and Scanty rainfall during the rest of the year (Rabi season) The total rainfall of the experimental site was 77.3 mm during the period of the experiment. The average maximum and minimum temperature were 24.6°C during the experimental period Rabi season in characterized by plenty of sunshine. The maximum and minimum temperature, humidity rainfall and soil temperature during the study period were collected from the Bangladesh Meteorological Department of climate division and World Weather.com. The data of Table 1 indicate that the climate condition of growth and production period of cauliflower.

**Table 1: Monthly record of temperature, relative humidity, rainfall and pressure of the experimental site during the period from November 2017 to March 2018.**

| Month | Temperature (°C) | | Relative Humidity(%) | Total rainfall (mm) | Pressure (mbar) |
|---|---|---|---|---|---|
| | Maximum | Minimum | | | |
| November, 2017 | 34 | 18 | 71 | 10.2 | 1010 |
| December, 2017 | 30 | 17 | 73 | 63.9 | 1013 |
| January, 2018 | 27 | 12 | 67 | 00 | 1012 |
| February, 2018 | 32 | 16 | 66 | 3.2 | 1012 |
| March, 2018 | 34 | 20 | 72 | 34.1 | 1009 |

**Sources:** Bangladesh Meteorological Department (climate and weather division) Agargaon, Dhaka.

### 3. 1. 3 Soil

The soil of the experimental area belongs to the Madhupur Tract (UNDP, 1988). The analytical data of the soil sample collected from the experimental area with the help of 60 cm auger from 0 to 30 cm and 30 to 60 cm depth of soil, then Primary samples were mixed to prepare and composite soil sample from each replication was drawn to study physicochemical properties of the experimental field and presented in table 2 Before treatment application for analyzing morphological characteristics, mechanical and chemical composition of soil were determined in the SRDI, Soil Testing Laboratory, Khamarbari, Dhaka (Table 2).

**Table 2: A. Morphological characteristics of the experimental field.**

| Morphological features | Characteristics |
|---|---|
| Location | Horticulture Garden, SAU, Dhaka |
| AEZ | Modhupur Tract (28) |
| General Soil Type | Shallow Red Brown Terrace Soli |
| Land Type | Medium High Land |
| Soil Series | Tejgaon Fairly Leveled |
| Topography | Fairly Level |
| Flood Level | Above Flood Level |
| Drainage | Well Drained |

**Table 2: B. Physical and chemical properties of the soil.**

| Characteristics | Value |
|---|---|
| **Particle size analysis** | |
| % Sand | 27 |
| % Silt | 43 |
| % clay | 30 |
| Textural class | silty-clay |
| PH | 5.6 |
| Organic carbon (%) | 0.45 |
| Organic matter (%) | 0.78 |
| Total N (%) | 0.03 |
| Available P (ppm) | 20.00 |
| Exchangeable K (me/100 g soil) | 0.10 |
| Available S (ppm) | 45 |

**Source:** Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

### 3. 2. 1 Plant Materials

Seed of cauliflower cultivar, Durga variety was used in the experiment. Seeds are collected from Tongi bazar, Gajipur, Dhaka.

### 3. 2. 2 Cropping history of the experimental field

The knowledge about previous crops of experimental field is essential to know its previous history. The experimental field was planted to different crops during past 3 seasons. A brief history of crops sequence followed during the last three years is shown in the Table 3.

**Table 3: Previous history of the experimental field.**

| Year | Kharif Season | Rabi Season |
|---|---|---|
| 2015-2016 | Rice | Tomato |
| 2016-2017 | Maize | Potato |
| 2017-2018 | Watermelon | Present experiment |

### 3. 2. 3 Raising of seedling

After selection of the proper site the soil was dug with the help of pick axe and the earth was made pulverized and fine. All the grassroots, bricks and stones were collected and thrown out. The beds were prepared and finally leveled and reached to fine tilt. FYM, urea, MP was added into each bed. Beds of 1.0 sq. m. (1.0 m X 1.0 m) were prepared. seeds of cauliflower were sown 7th November, 2017. Before sowing, seeds were soaked into overnight. After sowing the seeds were covered with light soil. Immediately after watered with the help of water can. Then fencing and shading of bed was provided by bamboo mat for protection. Care should be taken every day by watering which is very important for cauliflower cultivation, weeding etc. until transplanting to main field.

### 3. 3. 1 Preparation of main field through experimental design and layout

The land which was selected to conduct for the experiments was ploughed with disc plough and exposed field for a few days to penetrate direct sunshine to kill soil borne pathogens and soil inhabitant's insects. By mixing cow dung the land was ploughed and cross-ploughed with a power tiller followed by laddering to break up the soil clods to obtain unit good tilt and to level the land. The weeds, crop residues and stables were removed from the field. The soil was treated with Furadan 5G insecticide. After final land preparation, there were twenty-one experimental plot was laid out by following experimental design and layout, and the edge around each unit plot was raised to check run out of the nutrients.

### 3. 3. 2 Details of layout

There were seven treatments was laid out following Randomized Complete Block Design (RCBD) with three replications. An area of 11m X 18m was divided into three equal blocks. Each block was contained 7 plots where 7 treatments along with control treatment were allotted at random. Thus there were 21 unit plots altogether in the experiment. The size of each plot was 3m X 2m. The distance between two blocks and two plots were kept 0.5 m. Thirty day old seedlings were transplanted in the main field on 09 December 2017 following 60 X 45 cm spacing. Experimental design and details layout are shown in Fig1 and Table 4.

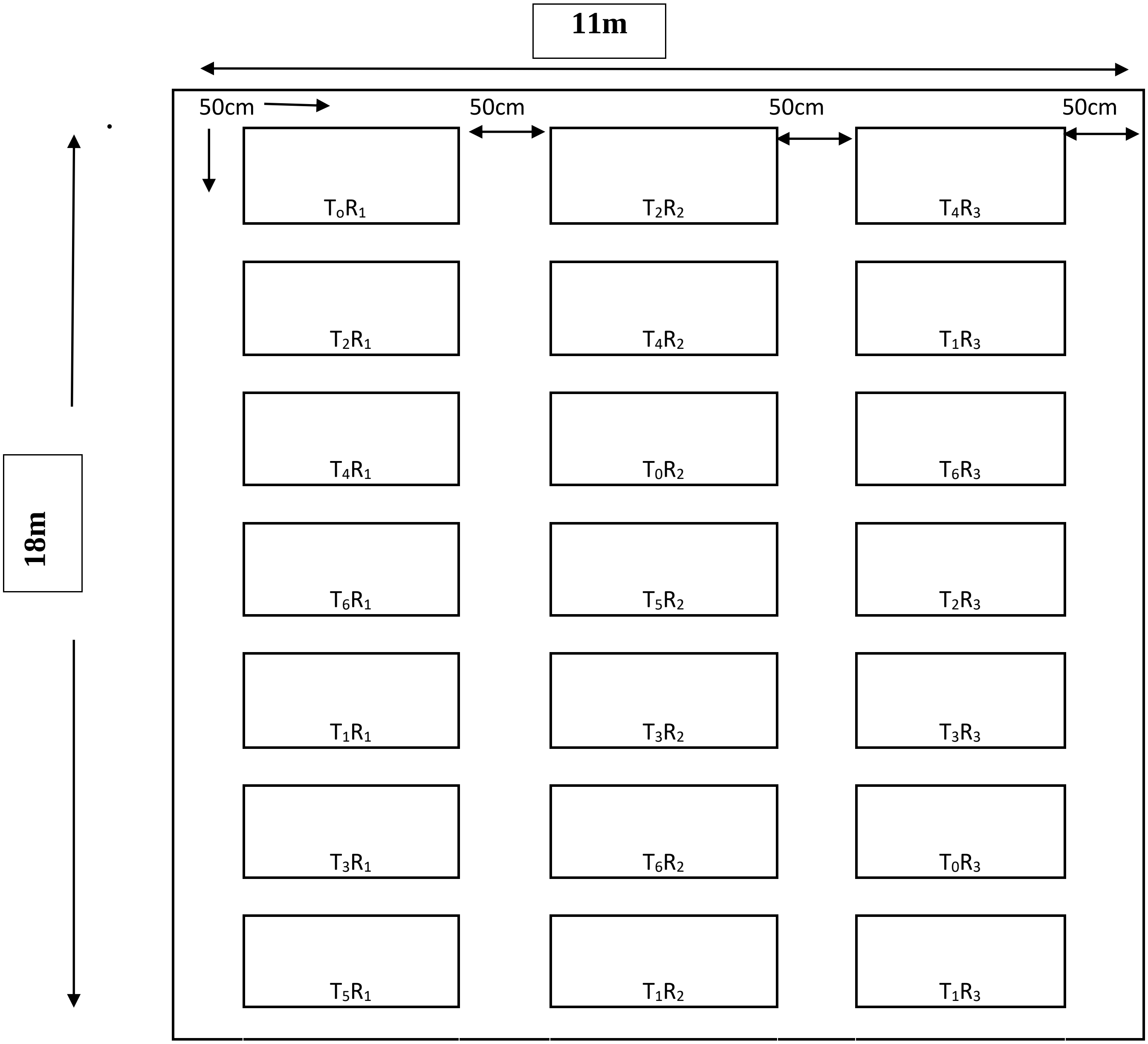



**Fig 1. a: Layout of experimental plot.**

| | 3m | | |
|---|---|---|---|
| | 1st row | (5 plants) | 2m |
| | 2nd row | (5 plants) | |
| | 3rd row | (5 plants) | |
| | 4th row | (5 plants) | |
| | | | |

**Fig 1. b: plot of experimental field.**

**Table 4: Details of layout of the experimental field.**

| | |
|---|---|
| Design | Randomized Complete Block Design |
| Replication | Three |
| Treatments | 07 |
| Total area of experimental field | 198 Sq. m |
| Total number of plots | 21 |
| Plot size | 3.00 X 2.00 Sq. m |
| Plot to plot distance | 50cm |
| Distance between replication | 50cm |
| Row to Row distance | 60cm |
| Plant to plant distance | 45cm |
| Number of rows in each plot | 04 |
| Number of plants per row | 05 |
| Total number of plants per plots | 20 |
| Num. of plants for observation per plot | 05 |
| Crop | Cauliflower |
| Variety | Durga hybrid |
| Season | Rabi, 2017-2018 |
| Date of sowing | 7.11.2017 |

### 3. 4 Treatments of the experiment

The experiment consisted of one factor because of their use were as follows:

**A.** Basal dose of micronutrients (Boron and Zinc) and Amount of plant growth regulators spraying after transplanting (25 and 35 DAT).

$T_{o=}$ $B_o$, $Zn_o$, $H_{o\ (Control)}$

$T_1$= 5 kg/ha B

$T_2$= 5 kg/ha Zn

$T_3$= 5 kg/ha B + 5 kg/ha Zn

$T_4$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm IAA

$T_5$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm $GA_3$

$T_6$= 5 kg/ha B + 5 kg/ha Zn + 50ppm IAA + 50 ppm $GA_3$

There are in total 21 treatment combinations along with control treatment and 7 treatments in each replication of the experimental plot. such as,

In $R_1$: $T_1R_1$, $T_2R_1$, $T_4R_1$, $T_6R_1$, $T_1R_1$, $T_3R_1$ and $T_5R_1$ respectively from west side to east side.

In $R_2$: $T_6R_2$, $T_3R_2$, $T_5R_2$, $T_1R_2$, $T_4R_2$, $T_2R_1$ and $T_1R_1$ respectively from west side to east side.

In $R_3$: $T_4R_3$, $T_1R_3$, $T_6R_3$, $T_2R_3$, $T_3R_3$, $T_1R_3$ and $T_5R_3$ respectively from west side to east side.

### 3. 5. 1 Preparation and Application of IAA and $GA_3$

Plant growth regulator Gibberellic Acid ($GA_3$), and Auxin (IAA) was collected from Hatkhola Road, Dhaka. A 1000 ppm Separate stock solution of IAA, $GA_3$ was prepared separately by dissolving 1 g of it in a small quantity of ethanol prior to dilution with distilled water in one liter of volumetric flask. The stock solution was used to prepare the required concentration for different treatment i.e. 50 ml of $GA_3$ stock solution was diluted in 1 liter of distilled water to get 50 ppm $GA_3$ solution. In a similar way, 50 ml of IAA stock solutions were diluted to 1 liter of distilled water to get 50 ppm IAA solution. Control solution also prepared only by adding a small quantity of ethanol with distilled water. IAA and $GA_3$ as per treatment were applied at two times 20 and 35 days after transplanting by a mini hand sprayer.

### 3. 5. 2 Application of manure and fertilizer

The sources of Nitrogen, $P_2O_5$, $K_2O$, Zinc, Boron as urea, TSP, MP, Zinc sulphate, Borax acid were applied respectively. All these are applied during final land preparation except urea. Urea was applied 2/3 portion when land preparation and rest portion was applied in two equal installments at 11 and 17 days after seedling transplanting. Well rotten cow dung 12.63 ton/ha also applied during final land preparation (Table 5).

**Table 5: Application procedure and percentage of manure and fertilizer.**

| Fertilizers and manures | Dose/experimental land(198sq.m) | Dose/ha | Application % | | |
|---|---|---|---|---|---|
| | | | Basal | 11DAT | 17DAT |
| Urea | 04 kg | 202 kg | 62.5 | 25 | 12.5 |
| TSP | 03 kg | 152 kg | 100 | -- | -- |
| MP | 2.5 kg | 126.26 kg | 100 | -- | -- |
| Boric acid | 99gm | 05 kg | 100 | -- | -- |
| Zinc sulphate | 99gm | 05 kg | 100 | -- | -- |
| Cow dung | 250 kg | 12.63 ton | 100 | -- | -- |

**3. 6 Seed transplanting**

Seedbed was watered for transplanting the seedlings to minimize the damage of roots. After one month, healthy seedlings were transplanted at the spacing of 60 cm × 45 cm in the plots on 09 December 2017. Thus the 20 plants were accommodated in each unit plot. Healthy seedlings transplanted having a boll of earth and Planting was done in the afternoon. Light irrigation by water cane was given immediately after transplanting around each seedling for their better establishment. Regular irrigation is necessary for cauliflower establishment. If temperature is higher, then transplanted seedlings should be shaded for five days with the help of banana leaf sheath to protect them from scorching sunlight.

**3. 7 Tagging**

Tagging was done few days after transplanting. Treatments were done in each plot on the basis of tagging in each replication.

### 3. 8 Intercultural operations

#### 3. 8. 1 Irrigation

Cauliflower required much water for better production. From seed sowing to establishment water is needed for establishment and production. Irrigation is done every 4 or 5 days after interval through watering cane for light irrigation when seedling phase and flowing water for heavy irrigation when development phase. It is also based on soil and climate condition which should also concentrate.

#### 3. 8. 2 Earthing up

It was done at 30 days after transplanting by piling soil up around the base of a plant. It can be done by hand using a hoe. At the time of earthing up the plants are supported with soil to avoid toppling of the plant during head formation.

#### 3. 8. 3 Blanching

Blanching was 4-5 days prior to harvest by covering curds with few leaves for protecting the curds from yellowing due to direct exposure to sun and saving for not losing flavor.

#### 3. 8. 4 Weeding

Weeding was done 22 days after transplanting to reduce competition of weeds with cauliflower plants for mineral, nutrients, water etc.

#### 3. 8. 5 Pest and disease control

Furadan 5G was applied when final land preparation as soil insecticide. Few cauliflower plant was damaged by cutworm at the time of establishment and controlled by using Karate or Mortar 48EC in 11no. days and 20 no. days after transplanting.  Also Chlropyrophos and Cypermetric group of insecticides could be used for controlling insects. Application of 5ml Karate insecticide added with 10 ml water mixture for spraying. Diseased plants and leaves are removed from field. All these activities are done in the afternoon.

### 3. 8. 6 Gap filling

Although under careful observation of seedlings, there are very few seedlings were damaged so some new healthy seedlings were replaced when needed. Needed seedlings come from experimental field, established within field margin and outside from the plot which are transplanted on the same date for future use as plants stock. Replacement was also done in the afternoon with same procedure of seed transplanting.

### 3. 8. 9 Harvesting

Harvesting of the cabbage was not possible on a certain or particular date because the curd initiation as well as curd at marketable size in different plants were not uniform. Marketable curds were harvested with stem by using as sharp knife. Randomly selected five plants were harvested from each plot at different date for data collection. $T_4$, $T_5$, $T_6$ treated plants were matured early as curd initiation date was only 43 no. day and harvesting date was 5 February 2018. After then $T_3$ treated plot harvested at 11 February, $T_1$ and $T_2$ treated plot harvested at 15 February and at last control treated plot harvested at 22 February 2018.

### 3. 9 Observation and its procedure

Five plants randomly from each plot were selected to record the various observations. The data were recorded as per the standard procedure and pertaining important characters along with parameter listed as follows.

### 3. 9. 1 Parameters

Parameters were considered for data collection of the experiment are given in the Table 6.

**Table 6: Data was recorded on following parameters of cauliflower.**

| | |
|---|---|
| 1. plant height | 11. Fresh Curd yield per bed |
| 2. plant canopy | 12. Marketable curd weight |
| 3. Number of leaves plant | 13. Marketable Curd yield per bed |
| 4. Length of leaves | 14. Marketable curd yield ton per ha |
| 5. Breadth of leaves | 15. Curd diameter |
| 6. Leaf area index | 16. Stem length of curd |
| 7. Chlorophyll content | 17. Fresh curd yield per bed |
| 8. Fresh Curd weight | 18. Dry weight of curd |
| 9. Root weight | 19. Dry weight of leaves |
| 10. Leaves weight | 20. Dry weight of roots |

### 3. 9. 2 Plant height at 40 DAT and 55 DAT (cm)

First plant height was recorded at 40 days and then 55 days after transplanting by a measuring scale from the base of the plant to the tip of the longest leaf.

### 3. 9. 3 Plant canopy at 40 DAT and 55 DAT (cm)

Plant canopy was recorded at 40 days and then 55 days after transplanting by a measuring scale that estimated the leaves of the plant covered the required area.

### 3. 9. 4 Length of leaves at 40 DAT and 55 DAT (cm)

The length of the biggest leaf was measured in the leaf of five selected plants with the help of measuring scale and then average was calculated from each treatment combination at 40and 55 days after transplanting.

### 3. 9. 5 Breadth of leaves at 40 DAT and 55 DAT (cm)

The Breadth of the biggest leaf was measured in the leaf of five selected plants with the help of measuring scale and then average was calculated from each treatment combination at 40and 55 days after transplanting.

### 3. 9. 6 Number of leaves at 40 DAT and 55 DAT

The total number of leaves per plant was counted from each selected plant. Data were recorded as the average of 5 plants selected at random of each plot at 40 and 55 days after transplanting.

### 3. 9. 7 Days from transplanting to curd initiation

Days required for curd initiation from transplanting was recorded from first curd initiation. The recorded day was 43no. day where $T_4$ and $T_6$ were applied.

### 3. 9. 8 Fresh leaves weight (kg)

Fresh leaves weight was recorded as the average of 5 plants selected at random of each plot with the help of a weighting balance just after harvest of the curd. It was expressed in kilogram (kg).

### 3. 9. 9 Fresh roots weight (kg)

Fresh root weight was recorded as the average of 5 plants selected at random of each plot with the help of a weighting balance just after harvest of the curd. It was expressed in kilogram (kg).

### 3. 9. 10 Dry weight of leaves (%)

The dry weight of five randomly selected plant's leaves from each plot was taken and allowed to sun drying for one month. Then it was kept in a drying oven at 70-72°C, AC 220V and 50Hz for 3 days to drying till its constant weight. After complete drying, the weight of dry leaves of each plot was recorded separately on electronic balance and the mean was computed.

### 3. 9. 11 Dry weight of roots (%)

The dry weight of five randomly selected plant's root from each plot was taken and allowed to sun drying for one month. Then it was kept in a drying oven at 70-72°C, AC 220V and 50Hz for

3 days to drying till its constant weight. After complete drying, the weight of dry roots of each plot was recorded separately on electronic balance and the mean was computed.

### 3. 9. 12 Stem length

A meter scale was used to measure the stem length of curd and expressed in centimeter (cm).

### 3. 9. 13 Chlorophyll content of leaves

SPAD meter (The Soil-Plant Analyses Development) was used to calculate the amount of Chlorophyll content of leaves. Each plants three leaves are selected and each leaves different portion such as top, middle bottom parts of leaves are recorded then calculated to mean number for accurate chlorophyll content value. SPAD unit of Minolta Camera Co. has developed the SPAD-502 chlorophyll meter (Minolta Camera Co., Japan), a hand-held, self-calibrating, convenient, and nondestructive lightweight device used to calculate the amount of chlorophyll present in plant leaves (Minolta, 1989; Yadava, 1985). This meter records optical density measurements at two wavelengths, converts them into digital signals, and then into a SPAD value (Minolta,1989).

### 3. 9. 14 Curd diameter

curd diameter was taken by using a measuring scale at the final harvest. Diameter of the curd was measured at different directions and finally the average of all directions was recorded and expressed in centimeter (cm).

### 3. 9. 15 Fresh curd weight (kg)

The curd weight with leaves and without leaves were recorded with the help of a weighting balance just after harvest of the curd. It was expressed in kilogram (kg).

### 3. 9. 16 Fresh curd yield (kg/plot)

Curd weight per plot were recorded by weighing all the cauliflower curds from each unit plot separately excluding roots and outer leaves and it was expressed in kilogram (kg).

### 3. 9. 17 Fresh Curd yield (ton/ha)

The yield per hectare was calculated by converting from the per plot yield data to per hectare and was expressed in ton (t).

### 3. 9. 18 Dry weight of curd (%)

The dry weight of five randomly selected curd from each plot was taken and allowed to sun drying for one month. Then it was kept in a drying oven at 70-72°C, AC 220V and 50Hz for 3 days to drying till its constant weight. After complete drying, the weight of dry curd of each plot was recorded separately on electronic balance and the mean was computed.

### 3. 9. 19 Marketable curd weight (kg)

Marketable curd weight was recorded after harvesting of curd when the extra leaves around the curd was pruned. It was measured with a weighing balance and expressed in kilogram (kg).

### 3. 9. 20 Marketable yield (ton/ha)

It consisted of only quality curd and was also calculated in ton per hectare by converting the total yield of curd per plot.

## 3. 10 Statistical analysis

The observations (data) for various growth and yield contributing characters were statistically analyzed to find out the significance of variation from the resulting treatments. The mean for all the calculated and the analysis of variance for each of the characters under study was done by Fisher-LSD test and each data analyzed by R-STAT software for Randomized Complete Block Design (RCBD). The treatment means were compared by Least Significant Difference (LSD) at 5% level of significance (Gomez and Gomez, 1984).

# CHAPTER IV

# RESULTS AND DISCUSSION

The experiment was conducted to find out the growth and yield of cauliflower as influenced by micronutrients and plant growth regulators. The analysis of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendices I-X. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following sub-headings.

## 4.1 Plant height

Significant variation was found on plant height of Cauliflower due to different type of micronutrients and plant growth regulators at 40 and 55 DAT in (Appendix I). At 40 DAT, after transplanting the highest plant height was found 45.32 cm in $T_6$ (5 kg/ha B + 5 kg/ha Zn + 50ppm IAA + 50 ppm $GA_3$) treatment which was statistically different from others. The second highest plant height was observed in $T_4$ (42.57cm) treatment whereas the lowest plant height was observed in $T_0$ (31.93cm) treatment and it was statistically similar to $T_1$, $T_2$ and $T_3$ treatment and statistically followed by $T_5$ (37.93cm) treatment.

At 55 DAT, the highest plant height was observed in $T_6$ (53.39 cm) treatment which was statistically similar to $T_4$ (51.03cm) and it was statistically followed by $T_5$ (42.86cm) and $T_2$ (41.37cm) treatment. On the other hand, the lowest plant height was observed from $T_0$ (35.13cm) treatment (Fig 2). Patil *et al.* (1987) noticed the maximum plant height with $GA_3$ at 50 ppm and Nayanmani and Gogoi, (2007) revealed that the growth attributes of cauliflower cv. Pusa Katki were influenced by different level of boron significantly. Combined application of Zn, Mn and B at 30 and 60 days after transplanting resulted into increased plant height, number of branches per plant, number of fruits per plant (Bose and Tripathi,1996) which are similar to present investigation.

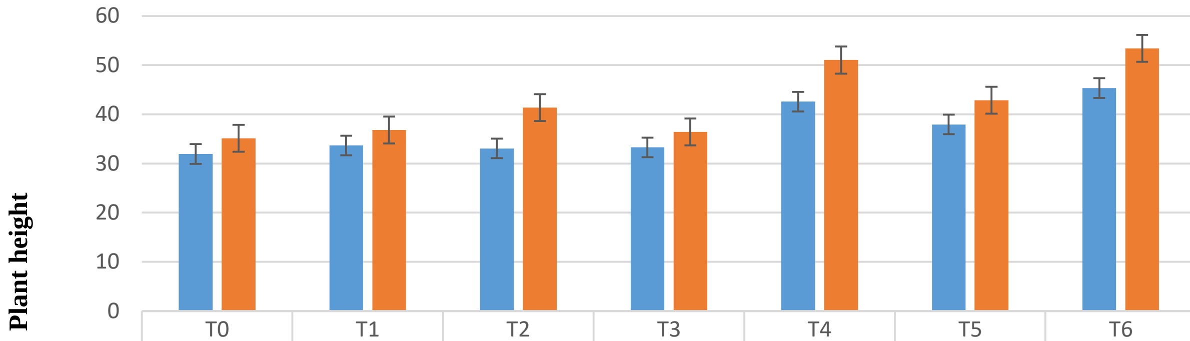
## 4. 2 Plant canopy

Significant variation was found on plant canopy of Cauliflower due to different type ofmicronutrients and plant growth regulators at 40 and 55 DAT in (Appendix II). At 40 DAT, the maximum plant canopy was recorded from $T_6$ (62.76 cm) treatment which was statistically followed (53.667cm and 53.07cm respectively) by $T_4$ and $T_5$ treatment whereas minimum plant canopy 42.03 cm was recorded from $T_0$ treatment which was statistically followed (44.36cm, 45.5cm and 47.46 cm respectively) by $T_1$, $T_2$ and $T_3$ treatment. At 55 DAT, the maximum plant canopy was recorded from $T_6$ (71.73 cm) treatment which was statistically followed by $T_4$ (63.43cm) treatment. The minimum plant canopy was 45.90cm was recorded from $T_0$ treatment and which was statistically similar to $T_1$ (47.93cm) treatment and followed (55.96cm, 54.26cm and 58.56cm respectively) by $T_2$, $T_3$ and $T_5$ treatment (Fig 3). Gonzalez *et al.* (2007) has conducted an experiment to know the effect of gibberellic acid application on growth of cauliflower (Var. *botrytis*.) and reported the favorable effect of gibberellic acid upon growth attributes which is supported the present findings of the experiment.

## 4. 3 Length of leaves

Length of leaves of Cauliflower plant showed significant variation due to different type of micronutrients and plant growth regulators at 40 and 55 DAT in (Appendix III). At 40 DAT, the maximum length of leaves were observed 28.21cm in $T_6$ treatment which was statistically followed 26.24 cm by $T_4$ treatment. And the minimum Length of leaves were 21.45 cm which was recorded from $T_1$ treatment which was statistically similar 21.73cm to $T_0$ control treatment and statistically followed (23.173cm, 23.93cm and 23.91cm respectively) by $T_2$, $T_3$ and $T_5$ treatment.

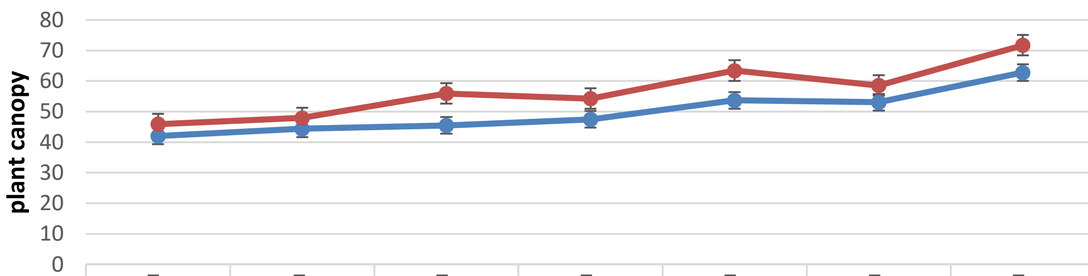
At 55 DAT, the maximum length of leaves were observed 31.61 cm in $T_6$ treatment which was statistically followed 29.5 cm by $T_4$ treatment. And similarly minimum Length of leaves were 23.32cm that was recorded from $T_0$ control treatment which was statistically followed 25.08cm by $T_1$ treatment (Table 7). Reddy (1989) conducted a field experiment on cauliflower and reported the greatest leaf length and breadth of curd were obtained with two application of urea & one application of $GA_3$ which is justify the present findings of the experiment.




| | T0 | T1 | T2 | T3 | T4 | T5 | T6 |
|---|---|---|---|---|---|---|---|
| Series1 | 31.93 | 33.66 | 33.05 | 33.26 | 42.57 | 37.93 | 45.32 |
| Series2 | 35.13 | 36.82 | 41.37 | 36.42 | 51.03 | 42.86 | 53.39 |

Treatments

**Fig 2: Effect of micronutrients and plant growth regulators on plant height at different dates.**




| | $T_o$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ |
|---|---|---|---|---|---|---|---|
| Series1 | 42.03 | 44.36 | 45.5 | 47.46 | 53.667 | 53.07 | 62.76 |
| Series2 | 45.90 | 47.93 | 55.96 | 54.26 | 63.43 | 58.56 | 71.73 |

Treatments

**Fig 3: Effect of micronutrients and plant growth regulators on plant canopy at different dates.**

Series 1: 40 days after transplanting,

Series 2: 55 days after transplanting.

Vertical bars represent LSD value at 5% level of significant.

$T_{o}$= $B_o$, $Zn_o$, $H_o$ (Control)

$T_1$= 5 kg/ha B

$T_2$= 5 kg/ha Zn

$T_3$= 5 kg/ha B + 5 kg/ha Zn

$T_4$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm IAA

$T_5$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm $GA_3$

$T_6$= 5 kg/ha B + 5 kg/ha Zn + 50ppm IAA + 50 ppm $GA_3$

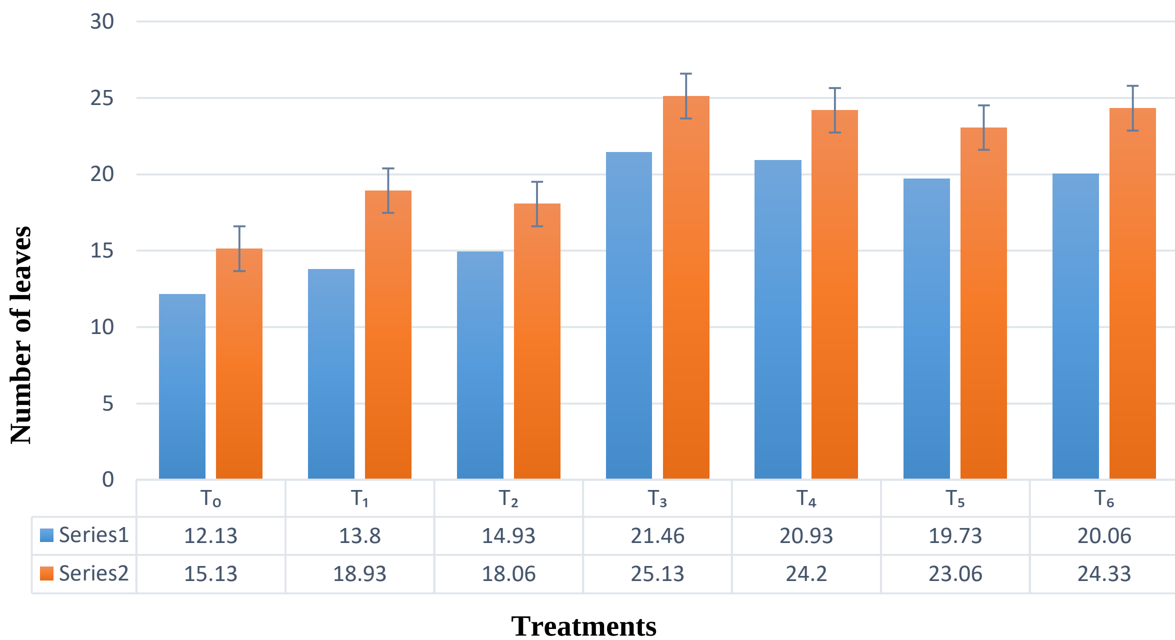



**Fig: 4 Effect of micronutrients and plant growth regulators on number of leaves on different dates.**

Series 1: 40 days after transplanting,

Series 2: 55 days after transplanting,

Vertical bars represent LSD value at 5% level of significant.

$T_{o}$= $B_o$, $Zn_o$, $H_o$ (Control)

$T_1$= 5 kg/ha B

$T_2$= 5 kg/ha Zn

$T_3$= 5 kg/ha B + 5 kg/ha Zn

$T_4$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm IAA

$T_5$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm $GA_3$

$T_6$= 5 kg/ha B + 5 kg/ha Zn + 50ppm IAA + 50 ppm $GA_3$.

## 4. 4 Breadth of leaves

Significant variation was recorded on breadth of leaves of Cauliflower plant due to different type of micronutrients and plant growth at 40 and 55 DAT in (Appendix IV). At 40 DAT, the maximum breadth of leaves were observed 16.38cm in $T_4$ treatment which was statistically followed (13.04cm, 14.11cm, 13.65cm, 13.74cm and 13.62 cm respectively) by $T_1$, $T_2$, $T_3$, $T_5$ and $T_6$ treatment. And the minimum breadth of leaves were 10.6cm which was recorded from $T_0$ treatment.And for 55 days, the maximum breadth of leaves were observed 18.41cm in $T_4$ treatment which was statistically similar 18.03 cm to $T_6$ treatment and statistically followed (17.23cm, 16.4cm and 16.77cm respectively) by $T_1$, $T_2$ and $T_5$. And the minimum breadth of leaves were 12.08cm which was recorded from $T_0$ treatment and statistically followed 16.12cm by $T_3$ treatment (Table 7).

## 4. 5 Number of leaves

Significant variation was recorded on number of leaves of Cauliflower plant due to different type of micronutrients and plant growth regulators at 40 and 55 DAT in (Appendix V). At 40 DAT, the maximum number of leaves were observed in $T_3$ (21.46) treatment which was statistically similar to $T_4$ (20.93) treatment and statistically followed by $T_5$ (20.06) and $T_6$ (19.73) treatment.
And the minimum number of leaves were observed in $T_0$ (12.13) treatment and which was statistically followed by $T_1$ (13.8) treatment and this also statistically followed by $T_2$ (14.93) treatment. At 55 DAT, the maximum number of leaves were observed in $T_3$ (25.13) treatment which was statistically similar to $T_6$ (24.33) and $T_4$ (24.2) treatment and statistically followed (23.06) by $T_5$ treatment. And the minimum number of leaves were observed in $T_0$ (15.13) treatment which was statistically followed by $T_1$ (18.93) and $T_2$ (18.06) treatment (Fig 4). Ghosh and Hasan (1997) reported that in cauliflower cv. Early Kunwari, treated with borax at the rate of 15 $kgha^{-1}$, produce highest number of 27.2 leaves per plant. Nayanmani and Gogoi (2007) revealed that the growth attributes of cauliflower cv. Pusa Katki were influenced by different level of boron significantly. Jordan *et al.* (2009) the effect of gibberellic acid, IBA and NAA as foliar spray cauliflower. The result indicated that growth characters like plant height, diameter of

**Table 7: Effect of micronutrients and plant growth regulators on leaves length, leaves breadth at different dates after transplanting in cauliflower**

| TREATMENTS | 40 days | | 55 day | |
|---|---|---|---|---|
| | Length of leaves (cm) | Breadth of leaves (cm) | Length of leaves (cm) | Breadth of leaves (cm) |
| $T_0$ | 21.73 d | 10.6 c | 23.32 e | 12.08 d |
| $T_1$ | 21.45 d | 13.04 b | 25.08 d | 16.4 bc |
| $T_2$ | 23.173 c | 14.11 b | 27.61 c | 16.77 bc |
| $T_3$ | 23.93 c | 13.65 b | 26.78 c | 16.12 c |
| $T_4$ | 26.24 b | 16.38 a | 29.5 b | 18.41 a |
| $T_5$ | 23.91 c | 13.74 b | 27.77 c | 17.23 b |
| $T_6$ | 28.21 a | 13.62 b | 31.6 a | 18.3 a |
| LSD(0.05) | 1.165 | 1.189 | 1.17 | 1.06 |
| CV% | 2.719 | 4.915 | 2.42 | 3.63 |

In a column means having same letter(s) are statistically similar and having different letter(s) are statistically dissimilar that differ significantly ($P<0.05$) according to LSD test.

$T_{o}$= $B_o$, $Zn_o$, $H_o$ (Control)

$T_1$= 5 kg/ha B

$T_2$= 5 kg/ha Zn

$T_3$= 5 kg/ha B + 5 kg/ha Zn$T_4$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm IAA

$T_5$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm $GA_3$

$T_6$= 5 kg/ha B + 5 kg/ha Zn + 50ppm IAA + 50 ppm $GA_3$.

**Table 8: Effect of different treatments on SPAD value and Stem length of cauliflower at different dates after transplanting.**

| TREATMENT | SPAD value | Stem length (cm) |
|---|---|---|
| $T_0$ | 51.15 b | 8.32 c |
| $T_1$ | 51.73 ab | 8.71 c |
| $T_2$ | 51.52 ab | 11.52 b |
| $T_3$ | 50.17 b | 8.69 c |
| $T_4$ | 52.29 ab | 14.83 a |
| $T_5$ | 50.94 b | 11.66 b |
| $T_6$ | 55.31 a | 15.11 a |
| LSD (0.05) | 3.96 | 1.77 |
| CV% | 4.29 | 8.87 |

In a column means having same letter(s) are statistically similar and having different letter(s) are statistically dissimilar that differ significantly ($P<0.05$) according to LSD test.

$T_o$= $B_o$, $Zn_o$, $H_o$ (Control)

$T_1$= 5 kg/ha B

$T_2$= 5 kg/ha Zn

$T_3$= 5 kg/ha B + 5 kg/ha Zn

$T_4$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm IAA

$T_5$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm $GA_3$

$T_6$= 5 kg/ha B + 5 kg/ha Zn + 50ppm IAA + 50 ppm $GA_3$.

## 4. 6 Chlorophyll content of leaves

Significant differences were recorded on Chlorophyll content of Cauliflower plant due to different type of micronutrients and plant growth regulators after harvesting in (Appendix V). At 51 DAT, maximum Chlorophyll content was recorded from $T_6$ (55.31) treatment and all the treatments result are statistically followed to $T_6$ treatment. Recorded value were (52.29, 51.73, 51.52, 51.15, 50.94, 50.17 respectively) obtained from $T_4$, $T_1$, $T_2$, $T_0$, $T_5$ and $T_3$ treatment. (Table 8).

## 4. 7 Stem length

Stem length of Cauliflower plant showed significant variation due to different type of micronutrients and plant growth regulators after harvest in (Appendix VI). After harvest the maximum stem length was recorded from $T_6$ (15.11cm) treatment and which was statistically similar to $T_4$ (14.83cm) treatment which was statistically followed by (11.52cm and 11.66cm respectively) by $T_2$, $T_5$ treatment. Minimum Stem length (8.32) which was recorded from $T_0$ treatment and statistically similar (8.69cm and 8.71cm respectively) to $T_1$ and $T_3$ treatment (Table 8). Aditya and Fordham (1995) reported that Higher concentration of boron markedly increased stem length but had no effect on number of leaves when applied prior to curd initiation attributes which is supported the experiment.

## 4. 8 Weight of green leaves and dry leaves

Weight of green leaves and weight of dry leaves showed significant variation due to different type of micronutrients and plant growth regulators after harvesting in (Appendix VII and X).

After harvesting the maximum weight of green leaves of Cauliflower were observed 766.73gm in $T_3$ treatment which was statistically similar (759.13gm and 754.06 respectively) to $T_4$ and $T_6$ treatment and statistically followed by $T_5$ (650.60gm) treatment. Minimum weight of green leaves Cauliflower were observed 327.78gm in $T_0$ treatment which was statistically followed (378.30gm and 376.46gm) by $T_1$ and $T_2$ treatment (Fig 5). After drying (sun and oven drying) of experimental leaves were weighted to calculate the statistical and significance variation. Maximum weight of dry leaves of Cauliflower were recorded 61.03gm in $T_3$ treatment which

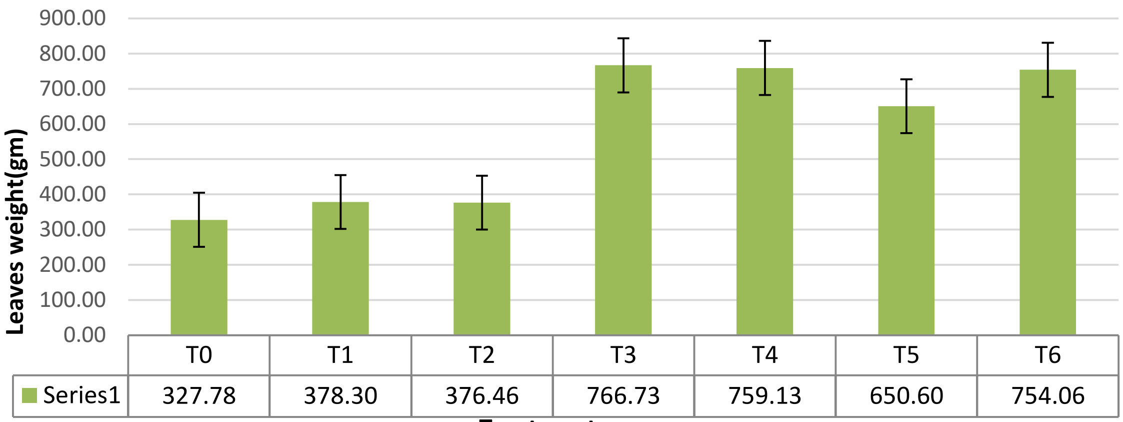



**Fig: 5 Effect of micronutrients and plant growth regulators on fresh leaves weight after harvesting in cauliflower.**

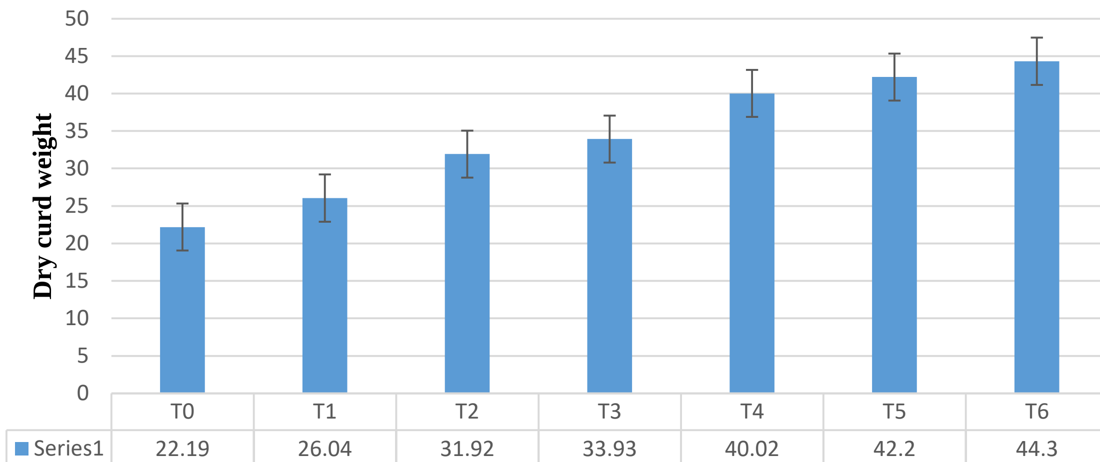



**Fig: 6 Effect of micronutrients and plant growth regulators on dry weight of curd after harvesting in cauliflower.**

Series 1: After harvesting

Vertical bars represent LSD value at 5% level of significant.

$T_{o}$= $B_o$, $Zn_o$, $H_o$ (Control) $T_1$= 5 kg/ha B

$T_2$= 5 kg/ha Zn $T_3$= 5 kg/ha B + 5 kg/ha Zn

$T_4$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm IAA $T_5$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm $GA_3$

$T_6$= 5 kg/ha B + 5 kg/ha Zn + 50ppm IAA + 50 ppm $GA_3$.

**Table 9: Effect of micronutrients and plant growth regulators on dry leaves weight and dry roots weight after harvesting.**

| TREATMENT | Dry leaf weight (gm) | Dry root weight (gm) |
|---|---|---|
| T0 | 33.32 c | 13.90 ef |
| T1 | 40.47 b | 13.56 f |
| T2 | 39.96 b | 15.42 de |
| T3 | 61.03 a | 16.93 d |
| T4 | 60.89 a | 18.85 c |
| T5 | 58.7 a | 22.54 b |
| T6 | 60.67 a | 28.02 a |
| LSD (0.05) | 4.005 | 1.66 |
| CV% | 4.4 | 5.08 |

In a column means having same letter(s) are statistically similar and having different letter(s) are statistically dissimilar that differ significantly ($P<0.05$) according to LSD test.

$T_o$= $B_o$, $Zn_o$, $H_o$ (Control)

$T_1$= 5 kg/ha B

$T_2$= 5 kg/ha Zn

$T_3$= 5 kg/ha B + 5 kg/ha Zn

$T_4$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm IAA

$T_5$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm $GA_3$

$T_6$= 5 kg/ha B + 5 kg/ha Zn + 50ppm IAA + 50 ppm $GA_3$.

was statistically similar to (60.89gm, 58.7gm, 60.67gm respectively) to $T_4$, $T_5$ and $T_6$ treatment. Minimum weight of dry leaves Cauliflower

were recorded 33.32gm in $T_0$ treatment which was statistically followed (40.47gm and 39.96gm respectively) by $T_1$ and $T_2$ treatment (Table 11).

**4. 9 Weight of normal roots and dry roots**

Weight of immediate harvested roots and weight of dry roots of cauliflower showed significant variation due to different type of micronutrients and plant growth regulators after harvesting (Appendix VII and X). After immediate harvesting the maximum weight of cauliflower roots were observed 155.87gm in $T_6$ treatment which was statistically followed by $T_5$ (138.73gm) treatment. Minimum weight of roots were observed 43.66gm in $T_1$ treatment which was statistically similar to $T_0$ (44.60gm) treatment and statistically followed (53.38gm, 58.16gm respectively) by $T_2$ and $T_3$ treatment (Table10).

After drying (sun and oven drying) the maximum weight of cauliflower roots were observed 28.02gm in $T_6$ treatment which was statistically followed (22.54gm) by $T_5$ treatment. Minimum weight of dry roots were observed 13.56gm in $T_1$ treatment which was statistically followed (13.90) by $T_0$ treatment. Treatments of $T_0$ and $T_1$ are statistically almost similar (Table 11). Abdel (1996) He observed increase in fresh and dry weight of root, root length and diameter and total yield increases in $GA_3$ concentration which is supported the experiment.

**4. 10 Relevant to cauliflower curd (Fresh curd weight, dry curd weight, curd diameter, and fresh curd yield/bed)**

Fresh curd weight, curd diameter, curd yield per bed and dry weight of Cauliflower curd showed significant variation due to different type of micronutrients and plant growth regulators after harvesting. These parameters were showed similar statistical variation with each other in (Appendix VI, VII, VIII and X). After harvesting the maximum number of fresh curd weight (1549.33gm), curd diameter (23.89cm), curd yield per bed (30986.67gm) and dry weight of

**Table 10: Effect of micronutrients and plant growth regulators on the weight of fresh curd, fresh roots and marketable curd and curd diameter after harvesting.**

| TREATMET | Fresh curd weight (gm) | Fresh root weight (gm) | Marketable curd weight (gm) | Curd diameter (cm) |
|---|---|---|---|---|
| T0 | 430.8 g | 44.60 e | 512.06 f | 9.98 g |
| T1 | 663.4 f | 43.66 e | 765.20 e | 15.39 f |
| T2 | 792.06 e | 53.38 d | 918.46 d | 17.54 e |
| T3 | 904.4 d | 58.16 d | 1427.66 c | 20.15 d |
| T4 | 1104.66 c | 109.27 c | 1648.20 b | 21.77 c |
| T5 | 1252 b | 138.73 b | 1675.53 b | 22.97 b |
| T6 | 1549.33 a | 155.87 a | 2113.00 a | 23.89 a |
| LSD (0.05) | 57.89 | 6.75 | 114.6 | 0.79 |
| CV% | 3.4 | 4.4 | 4.97 | 2.38 |

In a column means having same letter(s) are statistically similar and having different letter(s) are statistically dissimilar that differ significantly ($P<0.05$) according to LSD test.

$T_{o}$= $B_o$, $Zn_o$, $H_o$ (Control)

$T_1$= 5 kg/ha B

$T_2$= 5 kg/ha Zn

$T_3$= 5 kg/ha B + 5 kg/ha Zn

$T_4$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm IAA

$T_5$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm $GA_3$

$T_6$= 5 kg/ha B + 5 kg/ha Zn + 50ppm IAA + 50 ppm $GA_3$.

**Table 11: Effect of micronutrients and plant growth regulators on fresh curd yield/bed, marketable curd yield /bed after harvesting.**

| Treatment | Fresh curd yield/bed(gm) | Marketable curd yield/bed(kg) |
|---|---|---|
| T0 | 8616.00 g | 10.24 f |
| T1 | 13268.00 f | 15.30 e |
| T2 | 15841.00 e | 18.36 d |
| T3 | 18088.00 d | 28.55 c |
| T4 | 22093.33 c | 32.96 b |
| T5 | 25040.00 b | 33.51 b |
| T6 | 30986.67 a | 42.26 a |
| LSD (0.05) | 1158.039 | 2.29 |
| CV% | 3.4 | 4.9 |

In a column means having same letter(s) are statistically similar and having different letter(s) are statistically dissimilar that differ significantly ($P<0.05$) according to LSD test.

$T_o$= $B_o$, $Zn_o$, $H_o$ (Control)

$T_1$= 5 kg/ha B

$T_2$= 5 kg/ha Zn

$T_3$= 5 kg/ha B + 5 kg/ha Zn

$T_4$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm IAA

$T_5$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm $GA_3$

$T_6$= 5 kg/ha B + 5 kg/ha Zn + 50ppm IAA + 50 ppm $GA_3$.

Cauliflower curds (44.30gm) were recorded from $T_6$ treatment which was statistically followed by $T_5$ (1252.00gm, 22.97cm, 25040.00gm/ bed, 42.20gm respectively) treatment. Minimum fresh curd weight (430.80gm), curd diameter (9.98cm), curd yield per bed (8616.00gm) and dry weight of curd (22.19gm) were recorded from $T_0$ treatment and which was statistically followed by $T_1$ (663.40gm, 15.39cm, 13268.00gm/bed, 26.04gm) treatment (Fig 6 and Table 10, 11). Shirani *et al*. (2009), Neethu *et al*. (2015), Lendve *et al*. (2010), Mishra and Singh (1986), and Harris and Mathuma (2015) reported that $GA_3$ the improvement in the dry weight may be attributed to enhanced vegetative growth in combination of better utilization of ATP formation and better translocation of assimilated food from leaves to curd. Boron augments chlorophyll synthesis which leads better carbohydrate metabolism and formation of starch and all they lead to improved dry weight of the curd. which is justify the current experiment.

**4. 11 Relevant to marketable yield of cauliflower curd (Marketable curd weight, marketable curds yield per bed and marketable curds yield ton per hectare)**

Significant variation was recorded on marketable curd weight, marketable curds yield per bed and marketable curds yield ton per hectare of Cauliflower due to different type of micronutrients and plant growth regulators after harvesting in (Appendix IX). These parameters were showed similar statistical variation with each other. Maximum marketable curd's weight (2113.00gm), marketable curds yield per bed (42.26kg) and marketable curds yield ton per hectare (70.43ton) were recorded from $T_6$ treatment. Each maximum parameters were statistically followed by $T_4$ (1648.20gm, 32.96kg/bed and 54.94ton/ha respectively) treatment and $T_5$ (1675.53gm 33.51kg/bed and 55.85ton respectively) treatment. Minimum marketable curd weight (512.06gm), marketable curds yield per bed (10.24 kg) and marketable curds yield ton per hectare (17.06ton) recorded from $T_0$ treatment and which was statistically followed (765.20gm, 15.30kg, 25.50ton/ha respectively) by $T_1$ treatment (Fig 7). Kumar and Ray (2000) observed that the cauliflower cv. Plant shubhra treated with $GA_3$ 50mg per liter per liter concentration recorded greater curd circumference and significant increase in curd yield. Chattopadhyay and Mukhopadhyay (2003) observed that in cauliflower cv dania, the highest borax rate resulted in the maximum curd yield (330.19 q/ha). Voronova and Kozakov, 1983; Senthelhas *et al.*, 1987; Tadzhiryan, 1990; Tomar *et al.*, 1991 reported that promising results on yield and quality of

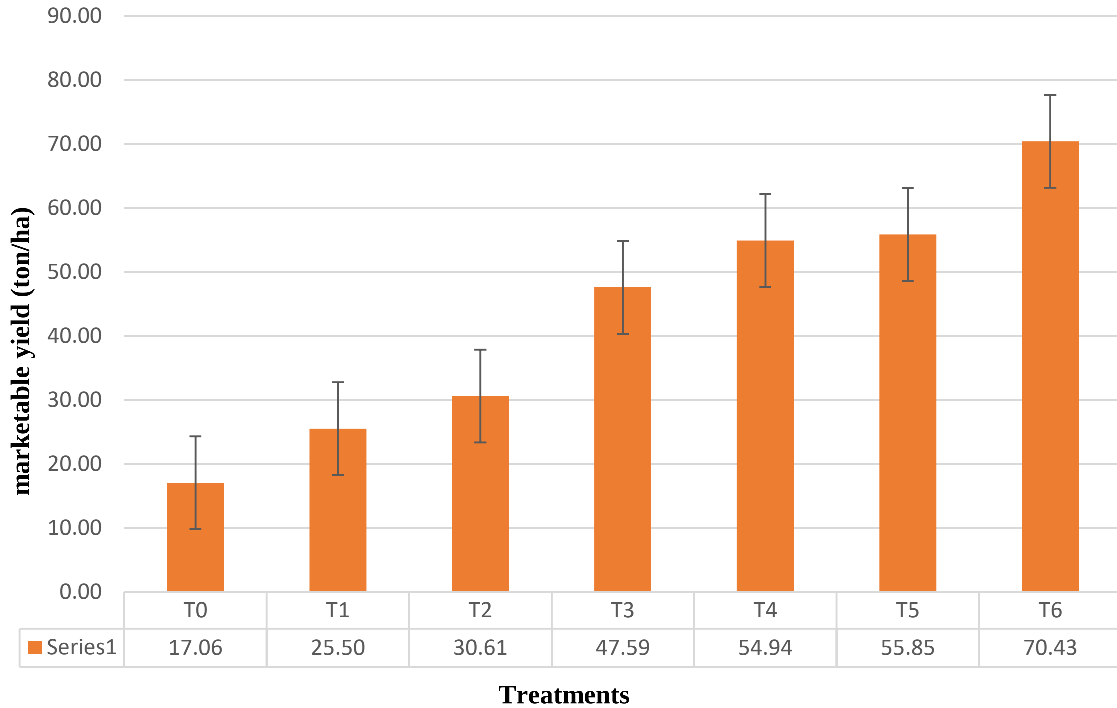



**Fig: 7 Effect of micronutrients and plant growth regulators on marketable yield after harvesting**

Vertical bars represent LSD value at 5% level of significant.

Series 1: after harvesting

To= Bo, Zno, Ho (Control) $T_1$= 5 kg/ha B

$T_2$= 5 kg/ha Zn $T_3$= 5 kg/ha B + 5 kg/ha Zn

$T_4$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm IAA $T_5$= 5 kg/ha B + 5 kg/ha Zn + 50 ppm $GA_3$

$T_6$= 5 kg/ha B + 5 kg/ha Zn + 50ppm IAA + 50 ppm $GA_3$

cauliflower and other crops due to the use of bio-chemical substances, such as Naphthalene acetic acid (NAA), Gibberellic acid ($GA_3$), Indole acetic acid (IAA) etc. which are justify the current experiment.

# CHAPTER V

# SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during Rabi season from November 2017 to February 2018 and was laid out in Randomized Complete Block Design (RCBD) with three replications. Objectives were to find out effect of Micronutrients and Plant growth regulators on Morpho-physiological characters and Yield of Cauliflower and data were recorded for that. The test crop used in the experiment was cauliflower variety 'Durga'. The experiment consisted of seven treatments. Treatments were (To: Bo, $Zn_o$, $H_{o\ (Control)}$; $T_1$: 5 kg/ha B; $T_2$= 5 kg/ha Zn; $T_3$: 5 kg/ha B + 5 kg/ha Zn; $T_4$: 5 kg/ha B + 5 kg/ha Zn + 50 ppm IAA; $T_5$: 5 kg/ha B + 5 kg/ha Zn + 50 ppm $GA_{3;}$ $T_6$: 5 kg/ha B + 5 kg/ha Zn + 50ppm IAA + 50 ppm $GA_3$) applied on equally divided (3m×2m) each 21 plot.

Most of the Morpho-physiological parameters in the experiment measured at 40 and 55 DAT, the tallest plant (45.32cm and 53.39cm respectively) was recorded from $T_6$ treatment whereas the shortest plant (31.93cm and 35.13cm respectively) was recorded from $T_0$ treatment. Maximum plant spread (62.76cm and 71.73cm respectively) was recorded from $T_6$ treatment whereas the minimum plant spread (42.03cm and 45.90cm respectively) from $T_o$ treatment. Highest length of leaves (28.21cm and 31.61 cm respectively) was recorded from $T_6$ treatment whereas the lowest length of leaves (21.45cm and 23.32cm respectively) from $T_1$ treatment and $T_o$ treatment. Maximum breadth of leaves (16.38cm and 18.41cm respectively) was recorded from $T_4$ treatment and minimum breadth of leaves (10.6cm, 12.08cm respectively) from $T_o$ treatment. The highest number of leaves (21.46cm and 25.13cm respectively) were recorded from $T_3$ treatment and Minimum number of leaves were (12.13cm and 15.13cm respectively) which was recorded from $T_0$ treatment. At 51 DAT, maximum Chlorophyll content (55.31) which was recorded from $T_6$ treatment and minimum Chlorophyll content 50.17 recorded from $T_3$ treatment.

After harvesting, maximum stem length (15.11cm) which was recorded from $T_6$ treatment and minimum Stem length (8.32cm) which was recorded from $T_0$ treatment. Maximum weight of green leaves of cauliflower (766.73gm) which was recorded from $T_3$ treatment and minimum weight of green leaves cauliflower were (327.78gm) from $T_0$ treatment. Maximum roots weight of cauliflower (155.87gm) which was recorded from $T_6$ treatment and minimum roots weight of cauliflower were (43.66gm) which was recorded from $T_1$ treatment. Maximum weight of fresh curd (1549.33gm) which was recorded from $T_6$ treatment and minimum fresh curd weight 430.80gm was recorded from $T_0$ treatment. Largest curd diameter (23.89cm) which was recorded from $T_6$ treatment and Smallest curd diameter 9.98cm was recorded from $T_0$ treatment. Maximum curd yield per bed (30986.67 gm/bed) which was recorded from $T_6$ treatment and minimum curd yield per bed (8616.00gm/bed) was recorded from $T_0$ treatment. Maximum marketable curd weight (2113.00gm) which was recorded from $T_6$ treatment and minimum marketable curd weight (512.06gm) was recorded from $T_0$ treatment. Maximum marketable curd yield per bed (42.26kg/bed) which was recorded from $T_6$ treatment and minimum curd yield per bed (10.24kg/bed) was recorded from $T_0$ treatment. Maximum marketable curd yield (70.43ton/ha) which was recorded from $T_6$ treatment and minimum marketable curd yield (17.06 ton/ha) which was recorded from $T_0$ treatment.

After drying, maximum dry weight of cauliflower curd (44.30gm) which was recorded from $T_6$ treatment and dry weight of cauliflower curd was (22.19gm) which was recorded from $T_0$ treatment. Maximum weight of dry leaves of cauliflower were (61.03gm) which was recorded from $T_3$ treatment and minimum weight of dry leaves cauliflower were (33.32gm) which was recorded from $T_0$ treatment. The maximum weight of roots of cauliflower were (28.02gm) which was recorded from $T_6$ treatment and minimum weight of dry roots Cauliflower were (13.56gm) which was recorded from $T_1$ treatment.

In case of micronutrient applied plant parameters within seven treatments at 40 and 55 DAT, higher plant height (33.66cm and 41.37cm respectively) were found from ($T_1$ and $T_2$ treatment). Larger plant canopy (55.96cm and 47.46cm) were found from ($T_3$ and $T_2$ treatment). Larger length of leaves (23.73cm and 27.61cm respectively) were recorded from ($T_3$ and $T_2$ treatment). Larger breadth of leaves (14.11cm and 16.77cm respectively) both were found from $T_2$ treatment. At 51 DAT, chlorophyll content (51.31) which was recorded from $T_1$ treatment.

After harvesting, higher leaf area index (3837.66), higher root weight of cauliflower (58.16gm), higher fresh curd weight (904.40gm), larger curd diameter 20.13cm, higher curd yield per bed (18088.00 gm), higher marketable curd weight (1427.66gm), higher marketable curd yield per bed (28.55kg gm) and higher marketable curd yield per hectare (47.59 ton) which all were recorded from $T_3$ treatment and the higher stem length (11.52cm) which was recorded from $T_2$ treatment. After drying, higher dry weight of cauliflower curd was (33.93gm) and higher roots weight of cauliflower were (16.93gm) which were recorded from $T_3$ the higher stem length (11.52cm) which was recorded from $T_2$ treatment.

Conclusion:

1. Combination of micronutrients ($T_3$: 5 kg/ha B + 5 kg/ha Zn) application showed better Morpho-physiological characters and better quality yield than single micronutrient treatment.
2. Combination of micronutrients and IAA plant growth regulators in ($T_4$ treatment) Showed better result in Morpho-physiological characters than Combination of micronutrients and $GA_3$ plant growth regulators ($T_5$ treatment) but $T_5$ treatment included higher yield and yield contributing characters than $T_4$ treatment.
3. $T_4$ treatment and $T_6$ treatment showed early curd initiation at (43 no. day) compared to other treatment application.
4. Finally, combination treatment of micronutrients and plant growth regulators or ($T_6$ treatment: 5 kg/ha B + 5 kg/ha Zn + 50ppm IAA + 50 ppm $GA_3$) on plants induced superior result of Morpho-physiological characters, best quality yield of cauliflower.

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Another plant growth regulator with different concentration need to be considered in different agro-ecological zones of Bangladesh for regional trial before final recommendation.
2. Another variety and management practices fertilizer may be used in future study.

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# APPENDICES

**Appendix I: Analysis of variance of the data on plant height at different dates after transplanting as influenced by different plant growth regulators and micronutrients in cauliflower.**

| Sources of variation | Degrees of freedom | Mean square | |
|---|---|---|---|
| | | Plant height | |
| | | 40 DAT | 55 DAT |
| Replication | 2 | 3.442 | 4.375 |
| Treatment | 6 | 83.675*** | 158.136*** |
| Residual | 12 | 1.265 | 6.294 |

*** Significant at 0.001 level of probability

**Appendix II: Analysis of variance of the data on plant canopy at different dates after transplanting as influenced by plant growth regulators and micronutrients in cauliflower.**

| Sources of variation | Degrees of freedom | Mean square | |
|---|---|---|---|
| | | Plant canopy | |
| | | 40 DAT | 55 DAT |
| Replication | 2 | 8.655 | 29.624* |
| Treatment | 6 | 153.770*** | 237.330*** |
| Residual | 12 | 5.562 | 6.769 |

* Significant at 0.05 level of probability
*** Significant at 0.001 level of probability

**Appendix III: Analysis of variance of the data on length of leaves at different dates after transplanting as influenced by plant growth regulators and micronutrients in cauliflower.**

| | Degrees of freedom | Mean square | |
|---|---|---|---|
| | | Length of leaves | |
| | | 40 DAT | 55 DAT |
| Replication | 2 | 4.1831** | 2.1848* |
| Treatment | 6 | 17.5131*** | 22.3520*** |
| Residual | 12 | 0.4295 | 0.4397 |

* Significant at 0.05 level of probability
** Significant at 0.01 level of probability
*** Significant at 0.001 level of probability

**Appendix IV: Analysis of variance of the data on breadth of leaves at different dates after transplanting as influenced by plant growth regulators and micronutrients in cauliflower.**

| Sources of variation | Degrees of freedom | Mean square | |
|---|---|---|---|
| | | Breadth of leaves | |
| | | 40 DAT | 55 DAT |
| Replication | 2 | 0.7394 | 0.075 |
| Treatment | 6 | 8.6599*** | 13.568*** |
| Residual | 12 | 0.4466 | 0.358 |

*** Significant at 0.001 level of probability

**Appendix V: Analysis of variance of the data on number of leaves at different dates after transplanting as influenced by plant growth regulators and micronutrients in cauliflower.**

| Sources of variation | Degrees of freedom | Mean square | | |
|---|---|---|---|---|
| | | Number of leaves | | Chlorophyll content of leaves |
| | | 40 DAT | 55 DAT | 41 DAT |
| Replication | 2 | 1.225* | 0.242 | 1.5637 |
| Treatment | 6 | 44.065*** | 44.751*** | 8.2022 |
| Residual | 12 | 0.289 | 0.460 | 4.9733 |

*** Significant at 0.001 level of probability * Significant at 0.05 level of probability

**Appendix VI: Analysis of variance of the data on curd diameter and stem length after harvesting as influenced by plant growth regulators and micronutrient in cauliflower.**

| Sources of variation | Degrees Of Freedom | Mean square | |
|---|---|---|---|
| | | Curd diameter | Stem length |
| Replication | 2 | 0.138 | 0.5041 |
| Treatment | 6 | 72.465*** | 24.7833*** |
| Residual | 12 | 0.201 | 0.9999 |

*** Significant at 0.001 level of probability

**Appendix VII: Analysis of variance of the data on curd weight, leaves weight and root weight after harvesting as influenced by plant growth regulators and micronutrients in cauliflower.**

| Sources of variation | Degrees of freedom | Mean square | | |
|---|---|---|---|---|
| | | Curd Weight | Leaves weight | Roots weight |
| Replication | 2 | 2996 | 530 | 55.4 |
| Treatment | 6 | 426373*** | 123825*** | 6774.0*** |
| Residual | 12 | 1059 | 276 | 14.4 |

*** Significant at 0.001 level of probability

**Appendix VIII: Analysis of variance of the data on fresh curd weight per plant and curd yield per bed and fresh curd yield per hectare after harvesting as influenced by plant growth regulators and micronutrients in cauliflower.**

| Sources of variation | Degrees of freedom | Mean square | |
|---|---|---|---|
| | | Fresh curd weight Per plant | Fresh curd yield per bed |
| Replication | 2 | 2996 | 1198469 |
| Treatment | 6 | 426373*** | 170549122*** |
| Residual | 12 | 1059 | 423738 |

*** Significant at 0.001 level of probability

**Appendix IX: Analysis of variance of the data on marketable curd weight per plant, marketable curd yield per bed and marketable curd yield per hectare after harvesting as influenced by different plant growth regulators and micronutrients in cauliflower.**

| Sources of variation | Degrees of freedom | Mean square | | |
|---|---|---|---|---|
| | | Marketable Curd weight per plant | Marketable curd yield per bed | Marketable curd yield per hectare |
| Replication | 2 | 174 | 0.07 | 0.19 |
| Treatment | 6 | 995863*** | 398.35*** | 1106.46*** |
| Residual | 12 | 4150 | 1.66 | 4.61 |

*** Significant at 0.001 level of probability

**Appendix X: Analysis of variance of the data on dry weight of curd, leaves and roots after drying as influenced by different plant growth regulators and micronutrients in cauliflower.**

| Sources of variation | Degrees of freedom | Mean square | | |
|---|---|---|---|---|
| | | Dry weight of curd | Dry weight of leaves | Dry weight of roots |
| Replication | 2 | 0.487 | 2.43 | 2.785 |
| Treatment | 6 | 207.854*** | 447.97*** | 82.217*** |
| Residual | 12 | 1.046 | 5.07 | 0.880 |

*** Significant at 0.001 level of probability

## List of plates

**Plate 1: Photograph showing seed sowing.**

**Plate 2: Photograph showing seedlings transplanting.**

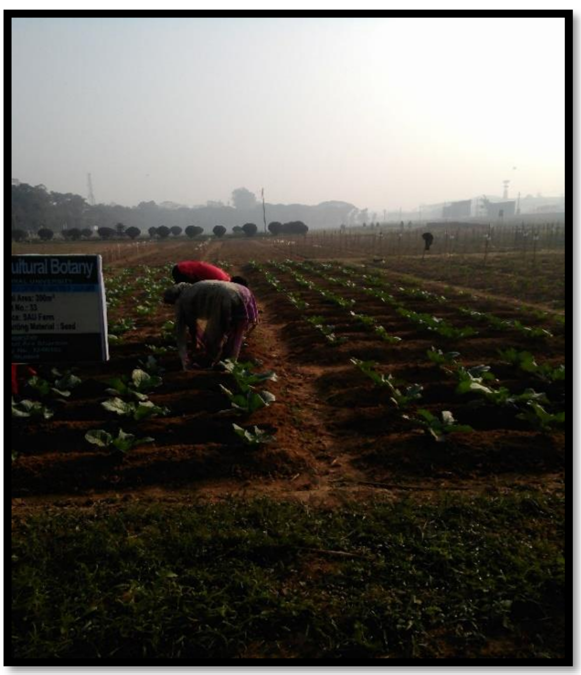

**Plate 3: Photograph showing working procedure of earthing up.**

**Plate 4: Photograph showing after earthing up**

**Plate 5: Photograph showing harvesting of cauliflower.**

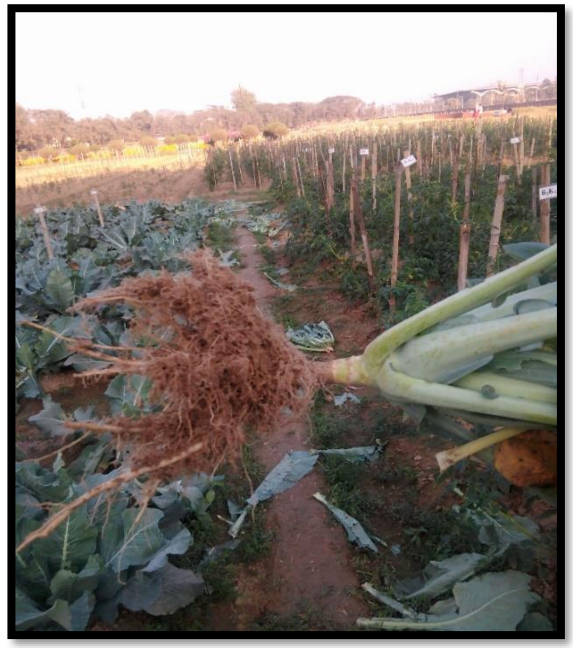

**Plate 6: Photograph showing uprooting of cauliflower plant.**

**Plate 8: Photograph showing curd of cauliflower**