EFFECT OF BORON AND MOLYBDENUM ON GROWTH AND YIELD OF CAULIFLOWER

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EFFECT OF BORON AND MOLYBDENUM ON GRWTH AND YIELD OF CAULIFLOWER

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CERTIFICATE

*This is to certify that the thesis entitled **"EFFECT OF BORON AND MOLYBDENUM ON THE GROWTH AND YIELD OF CAULIFLOWER"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **HORTICULTURE,** embodies the result of a piece of bona fide research work carried out by **MD. MINHAZ UDDIN SARKAR,** Registration No. 12-05149, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

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The Author

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ABBREVIATIONS AND ACRONYMS

ABBREVIATION	ELABORATIONS
AEZ	Agro-Ecological Zone
Anon.	Anonymous
ANOVA	Analysis of Variance
@	at the rate of
a.i	Active ingredient
Adv.	Advanced
Hort.	Horticulture
BARI	Bangladesh Agricultural Research Institute
SAU	Sher-e-Bangla Agricultural University
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
RCBD	Randomized Complete Block Design
CV	Coefficient of Variation
cv.	Cultivar
EC	Emulsifiable Concentrate
cm	Centimeter
df	Degrees of Freedom
DAT	Days After Trasplanting
Mo	Molybdenum
B	Boron
LSD	Least significance difference
et al.	and others
etc.	etcetera
FAO	Food and Agricultural Organization
RH	Relative humidity
Sci.	Science 's

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BY

MD. MINHAZ UDDIN SARKAR

ABSTRACT

The field experiment was conducted to investigate the effect of boron and molybdenum on growth and yield of cauliflower at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka. The experiment consisted of two factors such as Factor A: Boron (4 levels) as B_0: 0 (Control) B_1: 0.5 kg/ha, B_2:1 kg/ha, B_3:1.5 kg/ha and Factor B: Molybdenum (4 levels) as Mo0: 0 (Control) Mo_1:0.25 kg/ha, Mo_2: 0.50 kg/ha, Mo_3: 0.75 kg/ha. There were 16 treatment combinations and laid out in Randomized Complete Block Design (RCBD) with three replications. The influence of different levels of boron, molybdenum and their combined effect showed significant variations in growth andyield of cauliflower. In case of boron, the highest plant height (56.53 cm), numberof leaf (21.59), leaf length (43.98 cm), leaf breadth (21.20 cm), stem diameter (2.13 cm), curd diameter (14.51 cm), curd fresh wt. (637.25 g), dry matter % of curd (10.11), yield/plot (5.09 kg) and yield/ha (26.55 ton) were obtained from B_2 (1 kgB/ha). For molybdenum, Mo_2 (0.50 kg Mo/ha) produced the highest plant height (55.75 cm), number of leaf (21.01), leaf length (43.73 cm), leaf breadth (20.95 cm), stem diameter (2.17 cm), curd diameter (14.46 cm), curd fresh wt. (656.22 g), dry matter % of curd (10.60), yield/plot (5.24 kg) and yield/ha (27.34 ton). In combine treatments, the maximum plant height, number of leaves, leaf breadth, curd fresh weight,dry matter % of curd was produced from the treatment combination of B_2 (1 kg B/ha) with Mo_2 (0.50 kg Mo/ha). However, treatment combination of B_2Mo_2 (1 kg B/ha with 0.5 kg Mo/ha) performed the best results. So, 1 kg Boron/ha with 0.5 kg Molybdenum may use for cauliflower cultivation.

CHAPTER I

INTRODUCTION

Bangladesh is one of the world's largest producers of vegetables. But the quantity is much less than our requirements and serves per capita intake on only 126 g against the recommended requirement of 300g per capita per day for balance diet recommended by FAO and the World Health Organization (WHO, 2019).

Cauliflower (*Brassica oleracea var. botrytis* L.) is one of the most popular winter vegetables in Bangladesh (Akter *et al.*, 2011). It is a biannual and herbaceous vegetable crop under cruciferae family. It is used as a cooked vegetable, as soups, pickles, drying and also curries etc. It is nutritionally rich in vitamin and minerals. Cauliflower contains minimum fat, but higher amount of dietary fiber, folic acid, water, as well as L-ascorbic acid, possessing an affluent nutritional density. It is one of the highest antioxidative activity vegetables because of its high content of phytochemicals, such as glucosinolates, vitamins, phenolic compounds and fibers, which are principals for digestive system health (Podsedek, 2007; Picchi *et al.*, 2012). The health promoting properties of cauliflower have been strongly emphasized and were referred to its high content of sulphoraphane, indole-3-carbinol and 2-propenyl isothiocyanates, which are the breakdown productsof glucoraphanin, glucobrassicin and sinigrin, respectively (Agerbirk et al., 2009). Therefore, cauliflower has been shown to be very effective in protecting against the risk of several types of cancer (Lee *et al*., 2008; Tang *et al*., 2008). A high intake of cauliflower reduces the risk of aggressive prostate cancer (Report on the Productivity Survey of cauliflower Crop, 2014). One cup (100 g) of raw cauliflower supplies 2.5 g Dietary Fiber, 2.4 g Sugar, 37 mg Omega-3 fatty acid, 11 mg Omega-6 fatty acid, 13 IU vitamin A, 46.4 mg vitamin C, 0.1 mg vitamin E (Alpha Tokopherol), 16 mc vitamin k, 0.1 mg Thiamin, 0.1 mg Riboflavin, Niacin 0.5 mg, 0.2 mg vitamin B6, 57 mc Folate, 0.7 mg Pantothenic Acid, 45.2 mg Choline, 22 mg Calcium, 0.4 mg Iron, 15 mg Magnesium, 44.0 mg Phosphorus, 303 mg Potassium, 30 mg Sodium, 0.3 mg Zinc, 0.2 mg Manganese, 0.6 mc Selenium, 1 mc Fluoride, 18 mg Phytosterol, 0.7 g Ash and 91.9 g Water (Self Nutrition Data, 2018). Brassica vegetables present high levels of health-promoting nutrients and phytochemicals (that is, phenolics, glucosinolates, vitamins and minerals). Epidemiological studies indicate that the raise in the consumption of Brassicas is strongly associated with a reduced risk of degenerative diseases,cancer, cardio-vascular diseases and immunological disfunction (Francisco *et al*., 2017).

In Bangladesh cauliflower covered in an area of 40970 hectares with a total production of 2, 11,585 metric tons (BBS, 2015). It can be grown in all types of soil with good soil fertility (Islam, 2015). Cauliflower thrives very well in a cool moist climate and it does not withstand very low temperature or too much heat (Din *et al*., 2007).

Cauliflower is a heavy feeder and it requires large amounts of macronutrients as well as micronutrient. Cauliflower responds well to macro nutrients like nitrogen, phosphorus and potassium. However, micro nutrients are also essential for its proper growth and yield especially boron, molybdenum, iron, etc. It has a high micro-nutrients requirement, particularly boron and molybdenum. Among micronutrients, boron plays a vital role in crop production. It is an essentialmicronutrient for the growth of plant new cells. Boron is particularly important forcauliflower curd production.

Boron is very important for growth and development of cauliflower and is involved in cell division and hence helps in root elongation and shoot growth. The adequate development and production of brassicas depends very much on boron nutrition (Prado, 2008) since this element is important for meristematic tissues as it increases cell division. It plays a role in membrane metabolism and function, thereby being involved in enzymatic reactions, as well as the transport of ions, metabolites, and hormones. The element stimulates, inhibits, or stabilize enzymes; it is involved in the transport of sugars across the membrane, lignin and flavonoid synthesis, and metabolism of auxins, nitrogen compounds, and phenols This crop often shows the deficiency symptoms of boron and molybdenum. Deficiency symptoms of Boron consisting of browning of the curd, marginal mottling of the leaves and hollow condition of the stem. These disorders render curds unfit, for human consumption and reduce the curd yield considerably. The leaves of cabbage and cauliflower have a thick layer of epicuticular wax especially in the occurrence of boron deficiency (Pandey & Verma, 2017).

Boron normally becomes less available to plants with increasing soil pH. Yield and yield components of crops were affected positively and negatively by boron depending upon soil status, type of crop and the doses used. (Khanam *et al.,* 2000) found that the application of boron is essential for improving yield potentiality of chickpea and lentil at BAU farm soil in Bangladesh. Application of different levels of boron influenced the growth and yield in different crops also reported by Sohel *et al*. (2006) in broccoli. Singh et al. (2011) mentioned that enhancing levels of B has linear increased significantly in vegetative characters and cauliflower yield compared to control.

Molybdenum is also an essential micronutrient for the better growth and development of cauliflower. It helps in envelops of chloroplast in leaves. It is directly related to metabolic function of nitrogen in the plant through nitrate reductase enzyme that reduces the nitrate to nitrite and this is the first step of the incorporation of nitrogen to proteins (Bambara and Ndakidemi, 2010).

Molybdenum is needed by plants for chemical changes associated with nitrogen nutrition. In non-legume plants (such as cauliflower, tomatoes, lettuce and maize), molybdenum helps to take up the nitrates from the soil. Where the plant has insuffcient molybdenum, the nitrates are accumulated in the leaves and the plant cannot use them to make proteins. Moreover, molybdenum is essential for the process of atmospheric 'N'- fixation. It increases 'N'- fixing ability in plants and also helpful for the reduction of nitrates to ammonia prior to amino acid in the cell of the plants. These findings corroborate with their results obtained by Kumar (2004, 2005) and Mahmud et al. (2005).

Cauliflower responds severely to the deficiency of molybdenum that causes whiptail disorder. Again, the molybdenum deficiency appears on young plant with chlorosis of leaf margins and gradually the whole leaf turns white. As a result, the leaf blade fails to develop properly and only the midrib portions develop resulting sword like appearance of leaves giving whiptail symptom. Plant symptoms, resembling molybdenum deficiency became evident during early head development and application of molybdenum is very effective in preventing plant deterioration. Hunashikatti *et al*., (2000) reported that the combined application of 25 kg sulphur and 1 kg molybdenum per ha produced the maximum yield with a reasonable amount of ascorbic acid (49.12 mg/100g).

The present investigation was therefore, carried out with a view to achieving the following objectives:

- To investigate the effect of boron on growth and yield of cauliflower
- To investigate the effect of molybdenum on growth and yield of cauliflower
- To investigate the combined effect of boron and molybdenum on cauliflower production

CHAPTER II

REVIEW OF LITERATURE

Cauliflower is a commonly cultivated winter crop of Bangladesh. It is one of the most demandable vegetable crops of the world, particularly from the nutritional point of view. Different agricultural organizations and agricultural university conducted different research work on cauliflower among them BARI is one of the leading organizations of them. Among the micro nutrients, cauliflower responses highly to boron and molybdenum which is very crucial for the proper growth and development of cauliflower in Bangladesh. Investigations conducted by different workers also found that the application of different levels of boron and molybdenum influenced the growth and yield of various crops. Some of theimportant research findings available in this respect at home and abroad have beenpresented in this chapter.

2.1 Effect of boron on growth and yield of cauliflower

Seema *et al.* (2020) conducted a field experiment at Birsa Agricultural University, Kanke, Ranch. The results showed that the foliar application of combined micronutrients at 15, 45 and 75 days after sowing positively influenced the growth and yield of cauliflower. The yield was obtained 10.52 kg/plot in treatment combination of 0.2% Borax + 0.5% Manganese sulphate + 0.1% Ammonium molybdate whereas the minimum yield was recorded in control 6.50 kg/plot where only water was sprayed. Increase in number of leaves, plant height, stem length, stem diameter, plant spread, leaf area index and yield are positive effects. These micronutrients play a vital role in growth and development and their effects are concerned with particular characteristics or features like molybdenum is required for plant growth.

Based on the results obtained it can be concluded that for getting higher yield and good vegetative growth of the crop foliar application of 0.2% Borax+ 0.1% Ammonium molybdate + 0.5% Manganese sulphate at 15, 45 and 75 days after sowing.

Islam *et al.* (2015) conducted an experiment at the experimental field of department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during the winter (Rabi) season of 2012-13. 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 L3, 2 kg/ha treatment showed the opposite result. 2 kg B/ha was found to be an optimum rate.

Hussain *et al.* (2012) conducted a field experiment at the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh during winter season, 2007-2008 to determine the effect of N and B on the yield and hollow stem disorder of broccoli. Four levels of N as 0, 60, 120, 180 kg/ha and four levelsof B as 0, 0.5, 1.0 and 1.5 kg/ha consisting sixteen treatments were applied in a split plot design with three replications. The curd yield of broccoli was significantly increased with boron application up to 1.0 kg/ha. Plant height was significantly influenced by the different levels of B. The highest plant height (65.72 cm) was noted from the treatment receiving B at 1.0 kg/ha which was statistically similar to 0.5 and 1.5 kg B/ha. The interaction effect of N and B on yield and quality of broccoli was significant and the highest yield (16.68 t/ha) was recorded under 180 kg N and 1.0 kg B per hectare.

Firoz *et al.* (2008) studied the effect of boron fertilizer on the yield of broccoli through an experiment which was conducted at the Hill Agricultural Research Station (HARS), Khagrachari during September 2002 to March 2003.

The treatment consisted of three broccoli cultivars, viz., Green Commet, Green King and Green Harmony with three levels of boron viz., 0, 1 and 2 kg/ha. Boron was applied as solubor (20% B). There was a significant and positive effect of boron application on the yield of the crop. The 1.0 kg B/ha had the highest yield (512.30 g/plant). The application of boron at 1.0 kg/ha had the highest curd weight (294.60 g). Concerning varietal effect, curd weight as well as yield per plant significantly varied with different cultivars. Green Harmony performed the highest result (606.20 g/plant).

Moniruzzaman *et al.* (2007) conducted a field experiment comprising six levels of boron (0, 0.5, 1, 1.5, 2 and 2.5 kg/ha) and two levels of nitrogen (100 and 200 kg/ha) at the Agricultural Research Station, Raikhali, Rangamati Hill Districtduring 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. There were twelve treatments replicated three times. They reported that boron application increased plant height, number of leaves per plant, length and width of the leaves, plant spread, main head weight and head yield both per plant and per hectare significantly up to 1.5 kg/ha. Maximum yield per hectare was obtained at 2 kg B plus 200 kg nitrogen per hectare which was at par with 1.5 kg B plus 200 kg N perhectare and 1.5 kg B plus 100 kg nitrogen per hectare. The latter combination (1.5 kg B/ha + 100 kg N/ha) gave the lowest hollow stem in broccoli during both years.

The contribution of foliar application of different micronutrient mixture to increase in yields can be attributed to the enhanced availability of essential plant nutrients at the required growth stages, which, increased rate and efficiency of metabolic activities resulting in high assimilation of proteins and carbohydrates, which in turn helped in better nutrient absorption by plants resulting in better yields. The results obtained corroborated with the reports of Kanujia *et al.* (2006) Nandi and Nayak (2008) and Yadav *et al*. (2009).

Dhruba *et al.* (2009) conducted at Paklihawa Campus of the Institute of Agriculture and Animal Science, Rupandehi, Nepal, during Oct 2004 to Feb 2005 to study the effects of boron and phosphorus on the soil nutrient status, nutrient uptake by plant and yield of cauliflower (Brassica oleracea var. botrytis L.) varietySnowball-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, 90kg P2O5ha-1) were included. Curd yield, harvest index, boron and phosphorus uptake by plant and available boron in soil were significantly increased by the application of boron and phosphorus in soils. Available phosphorus in soils after the crop harvest was significantly increased by phosphorus application. The highest curd yield, boron and phosphorus uptake by plant as well as available boron and phosphorusin 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 1.3kg boron ha-1 while the phosphorus uptake was increased with increased application of phosphorus up to 90 kg P_2O_5 ha-1. Highly significant positive correlations between curd yield and leaf boron content as well as curd yield and plant phosphorus content were observed.

Pieztta *et al.* (2005) observed the effect of boron fertilizer on the yields of broccoli, cauliflower and cabbage through a field experiment carried out in Sao Paulo, Brazil, on a sandy soil low in available boron. Five boron levels (0, 2, 4, 6 and 8 kg/ha B as borax) were applied in broccoli, cauliflower and cabbage. Organic manure and chemical fertilizers, including borax were applied in the planting furrow before seedling transplant and plants were harvested at 63-93 daysafter planting date. The yield intervals obtained with broccoli cauliflower and cabbage varied according to the following intervals, 16.90-20.50 t/ha, 21.60-29.60 t/ha and 40.50-46.30 t/ha, respectively. The increase in production observed in broccoli and cabbage yield was linear with boron levels and the boron effect on cauliflower yield.

For maximum cauliflower yield (30 t/ha), treatment with 5.10 kg/ha of B was necessary. Broccoli and cabbage were less sensitive than cauliflower to boron deficiency and toxicity. Quality of the curds decreased when 2 or 6 kg/ha B was applied to cauliflower.

A glass house experiment by Annesar *et al.* (2004) with various macro and micro nutrients was carried out in 2004 at Wiehenstephan, Bavaria. Broccoli was grown in plots with a black beltic peat substrate. The typical nutrient deficiency symptoms of nitrogen, phosphorus and potassium under supply were described. Over supply of nutrients produced necrotic spots on old leaves. No deficiency symptoms were found for magnesium, iron, zinc, copper and manganese. Boron and molybdenum deficiency and sodium chloride, boron, zinc and manganese oversupplied caused severe damage.

Waltert and Theiler (2003) conducted an experiment on the effects of growth of different cultivars of Cauliflower and Broccoli were analyzed by the diameter of curd, stem and weight of curd and showed that there was a strong correlation between the diameter of stem and plant biomass and diameter of stem and curd. Growth of stem and curd diameter is dependent on days after transplantation in the field, but dependence is even stronger if related to the sum of maximum daily temperature. Growth of curd showed higher cultivar variation and was more sensitive to environmental factors than growth of stem. In consequence there is a higher variation between curds of one crop, which differs between cultivars. Depending on the correlations and the variation of harvesting period for cultivars can be predicted.

Singh (2003) studied the effects of B on the growth and yield of cauliflower cv. Pusa Synthetic in Chiplima, Orissa, India during the rabi season of 1997/98 and 1998/99. The treatments consist of borax applied at various rates and methods, 10 kg/ha as soil treatment, 5 kg/ha as soil Treatments + 0.25 as foliar spray at 45 and 65 days after planting, 5 kg/ha as soil treatment + 0.5% as foliar spray at 45 and 60 DAP, 0.25 or 0.5% as foliar spray at 45 and 65 DAP and 0.25 and 0.5% as foliar spray at 30, 45 and 60 DAP. B significantly improved the vegetative growth and quality parameters of cauliflower. The greatest stalk length (6.78 cm) was obtained with Borax applied at 10 kg/ha as soil treatment. Borax applied at 5 kg/haas soil treatment + 0.25% as foliar spray at 45 and 60 DAP resulted in the highest number of leaves per plant (17.4), leaf area (374.6 cm), curd weight (510 g), curd width (15.68 cm), curd length (8.48 cm), curd yield per plot (16.23 kg), curd yield per ha (140.86 quintal), net profit (51203 rupees/ha) and benefit cost ratio (4.20).

Jana and Mukhopadhaya (2002) conducted an experiment on the effect of boron, molybdenum and zinc on the yield and quality of cauliflower seed. They reported that higher seed yield and seed quality were observed by applying boron at the rate of 20 kg borax per hectare as compared to no boron application. The combined effect of boron, molybdenum and zinc showed significant increase in number of primary inflorescence stalks (8.70 per plant), pods per plant (1085.70) and seed yield (489.30 kg/ha).

Kumar *et al*. (2002) have also reported beneficial effect of micro- nutrients on cauliflower growth and yield. The growth and yield of cauliflower was significantly affected among boron sources. The granubor-II recorded 1.1,2.3, 2.4 and 3.7 per cent increase over borax with respect to plant height, stalk length, curd diameter and curd yield. The higher solubility of granubor-II might have increased B uptake by plant, resulting better growth and yield. The cauliflower height was not affected due to B rates. However, stalk length, curd diameter and curd yield was significantly influenced by boron level and themaximum increase in these parameters was observed with 1.5 kg B/ha. Differential response to graded levels of boron of cauliflower in biomass production at mid bloom stage particularly in soils having low to marginal content of available boron was recorded. The magnitude of response was in the range of 45 to 50 percent higher yield over control. The plant critical concentration ofboron was 21.0 and 20.40 mg/kg for the graphical and statical methods, respectively.

The effect of molybdenum (0.5 and 1 kg sodium molybdate/ha) and boron (10 and 20 kg borax/ha), applied alone or in combination with 25 tons farmyard manure/ha, on the yield and yield components of cauliflower cv. Pusa snowball-1 were determined by Kumar *et al.* (2002) in a field experiment conducted in Kullu, Himachal Pradesh, India from October to March of 1995-97. Molybdenum and boron application significantly increased curd diameter, weight and yield in the absence of farmyard manure. Borax at 10 kg/ha and molybdenum at 0.5 kg/ha increased the yield by 32 and 14%, respectively. Application of FYM in addition to 10% recommended NPK enhanced the yield of cauliflower by about 27% compared to application of NPK alone.

Singh *et al.* (2002) conducted a field experiment with cauliflower (cv. Snowball-16) during the rabi season of 1996-99 in Bihar, India. Four levels of B were applied at 0.05, 1.0 and 2.0 kg/ha as borax, 11% B and band placed around each plant one week after transplanting. Soil application of B significantly produced higher marketable curd yield of cauliflower over control in all three years. Application of boron upto 1.0 kg/ha significantly increased the yields. The highest B content in leaf tissue (23.77 mg/kg) and curds (19.31 mg/kg) was recorded upon treatment with 2.0 kg B/ha. B concentration in the leaf tissue was higher than that in the marketable curds.

Sharma *et al*. (2002) conducted a field experiment in Kandaghat, HimachalPradesh, India, during 1993-94 and 1994-95 on a sandy loam soil to determine the response of cauliflower cv. Pusa Snowball K-1 to different levels of boron (5, 15, 25 kg borax/ha) through soil application. Maximum plant height, number of brunches per plant, number of seeds per pod, seed yield per plant (32.67 g) and per hectare (9.80 q/ha) basis, 1000-seed weight and percent seed germination were obtained when 25 kg borax/ha was applied through soil application.

Yang *et al.* (2000) studied the effect of B-Mo treatments on curd yield and active oxygen metabolism in broccoli. When the concentration of B was the same,catalase (CAT) actively and antiscorbutic (ASA) content increased with increases in Mo concentration. Similar increases in CAT activity and ASA content were obtained with increases in B concentration at uniform Mo concentrations. The concentration of B and Mo at 6 and 5 g/litre, respectively, increased superoxide dismutase (SOD), peroxidase (POD), and nitrate reductase (NR) activity, decreased malondialdehyde content and autooxidation rate, inhibited membrane lipid peroxidation and increased curd yield.

An experiment was conducted by Prasad *et al.* (2000) with cauliflower cv. Pusa, conducted at Ranchi during 1993-96, revealed that application of 1 kg B/ha was sufficient for mid-season cauliflower, irrespective of the application method (broadcast and hand placement in one and two installments, and foliar spraying were tested).

2.1 Effect of Molybdenum on growth and yield of Cauliflower

Sani *et al.* (2018) were conducted an experiment in the Central Farm, Sher-e- Bangla Agricultural University, Dhaka from November 2015 to February 2016 with the aim of investigating the growth and yield attributes of cauliflower as influenced by different micronutrients and plant spacing. The experiment consisted of two factors, such as Factor A: Plant spacing (3 levels) as- S1: 50 cm ×50 cm, S2: 50 cm × 40 cm, S3: 50 cm × 30 cm and Factor B: Levels of micronutrients (4 levels) as- T0: B0Mo0 (control), T1:B1.0Mo0.5 kg/ha, T_2: B_2.0Mo1.0 kg/ha, T_3: B_3.0Mo1.5 kg/ha. For micronutrients, T_2 treatment produced the highest curd yield (46.85 t/ha) and the lowest (24.41 t/ha) was from control. In case of combined effect, the highest curd yield (51.56 t/ha) was obtained fromS_2T_2 and the lowest curd yield (20.33 t/ha) from S_1T_0. Therefore, it can be suggested that the highest curd yield and good shape cauliflower curd can be obtained in plant spacing 50 cm × 40 cm with the combined application of B 2.0 kg/ha and Mo 1.0 kg/ha.

An experiment was conducted in the Department of Horticulture, Birsa Agricultural University, Ranchi, during 2018. Results revealed that plant height, number of leaves per plant, stem length, stem diameter, plant spread, leaf area index and marketable yield of cauliflower, all were found significantly higher in the combined foliar application of 0.2% Borax + 0.5% Manganese sulphate +0.1% Ammonium molybdate.

A field experiment was conducted by Singh *et al.* (2017) during the winter season of the year 2012-13 to assess the efficacy of various levels of boron and molybdenum on growth, yield and quality of cauliflower (Brassica oleracea L. var. botrytis). The treatments comprised with foliar application of boron @ 100 ppm and molybdenum @ 50 ppm alone and in combination and two levels of borax @

10 and 20 kg/ha and sodium molybdate @ 1 and 2 kg/ha alone and in combination. The control treatment (NPK @ 120: 60: 60 kg/ha) was also laid out. There were quadratic responses of curd yield, plant weight and plant boron uptake to the applied boron; quadratic response of plant molybdenum uptake to theapplied molybdate, while the responses of curd yield, and plant weight to the applied molybdenum were linear. Highly significant positive correlations between curd yield and leaf boron content as well as curd yield and plant molybdenum content were observed. In conclusion, among the various treatments, the combinedapplication of borax 20 kg/ha and sodium molybdate 2 kg/ha as soil application in combination of recommended dose of NPK @ 120: 60:60 kg/ha (T12) gave the maximum height of the plant, length of leaf, width of leaf, total weight of plant, width of curd, average weight of curd and curd yield.

Singh *et al.* (2016) conducted an experiment consists of 10 treatments viz, T0 (control), T1 (B), T2 (Mo), T3 (Mn), T4 (B + Mo), T5 (B+ Mn +Zn), T6 (Mo +Mn), T7 (B +Mo +Mn +Zn), T8 (B +Zn), T9 (Zn) laid out in Randomized Block Design (RBD) with three replications. The micronutrients (B, Mo, Mn and Zn) were applied at the rate of 2 kg (B), 0.5 kg (Mo), 2.5 kg (Mn), 3 kg (Zn) per hectare significantly increased the plant height (51.30 cm), number of leaves(22.92), Plant spread (52.83 cm), diameter of bud or head (16.90 cm),average bud weight of per plant (303.69 gm), yield ha-1(121.48q), vitamin „C‟ (93.92 mg), TSS (0Brix) (8.37) content, Plant fresh weight(908.28 gm), dry plant matter(95.61 gm), root weight (45.02 gm) and dry weight(11.65 gm) were maximum in treatment T5 and lowest in T0 (control) under Allahabad agro climatic condition.

Ningawale *et al.* (2016) was carried an experiment out in randomized block design with four replications using Snowball-16 variety. The treatment combinations consist of T1 (Control), T2 (Borax @ 100 ppm as foliar spray), T3 (Ammonium molybdate @ 50 ppm as foliar spray), T4 (Borax @ 100 ppm + ammonium molybdate @ 50 ppm as foliar spray), T5 (Borax @ 10 kg/ ha as soil application), T6 (Borax@ 20 kg/ha as soil application), T7 (Ammonium molybdate @ 1 kg/ha as soil application), T8 (Ammonium molybdate @2 kg/ha as soil application),T9 (Borax @ 10 kg/ha + ammonium molybdate @1 kg/ha as soil application),T10 (Borax @ 10 kg/ha + ammonium molybdate @2 kg/ha as soil application),T11 (Borax @ 20 kg/ha + ammonium molybdate @1 kg/ha as soil application) and T12 (Borax@ 20 kg/ha + ammonium molybdate@1 kg/ha as soil application, Borax contain 11% boron and ammonium molybdate contain 98.99% tracer element). The crop was grown with the recommended dose of N: P: K (100:60:80 kg/ha) and FYM@ 200q/ha. Full dose of phosphorus, potash half dose of nitrogen along with different doses of boron and molybdenum (as per treatments) were applied as soil application before transplanting. The remaining half dose of nitrogen was applied at 30 days after transplanting (DAT) and three consecutive foliar sprays of different doses of boron and molybdenum (as per treatments) was done at 10 days interval starting from 30 DAT. Thirty eight days old healthy and uniform seedlings of cauliflower were transplanted on 24 November 2009 in the experimental field at a spacing of 60 cm × 45 cm. Observations on plant height, number of leaves/plant, length of leaves, width of leaves, stem girth, diameter of curd, fresh weight of curd, yield/plot, yield/ha, grading percentage of curds anddry matter of curd percentage were recorded on plants from each replication.

The experiment was conducted in the experimental field of Department of Horticulture, College of Agriculture, Rewa under Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during the rabi season 2009-2010. The results showed that morphological characters of cauliflower (*Brassica oleracea* var. *botrytis* L.) increased significantly with the different levels of boron and molybdenum at every stage of observation. At 60 DAT, the maximum plant height (34.35cm), number of leaves/plant (19.45), leaf length (32.02 cm), leaf width (28.31 cm) and stem girth (5.14 cm) were recorded in treatment T9, whereas the minimum plant height (32.50 m), number of leaves/plant (16.49), leaf length (29.07 cm), leaf width (25.72 cm) and stem girth (4.50 cm) were observed in control treatment T1. Yield and quality parameters were also influenced significantly due to various treatmentsof boron and molybdenum. The highest curd diameter (18.41cm), fresh- weight of curd (1.24 kg), yield/ha (400.29 q) and dry matter of curd (11.37 %) were recordedin treatment T9, whereas the lowest curd diameter (15.52 cm), fresh weight of curd (0.69 kg), yield/ha (218.28 q) and dry matter of curd (0.69 %) were found in control treatment T1. The treatmentT9 was found significantly superior over allthe treatments. The treatment T8 registered the maximum 'A' grade curds (52.54%) as well as 'B' grade curds (35.20%) and the lowest 'C' grade curds (12.26%). This was equally followed by T7and T9 treatments. The lowest 'A' grade curds 46.57% were found in case of control treatment T1, this was followed byT2 giving 46.64% 'A' grade curds, 33.09% 'B' grade curds and 20.01% C grade curds.

Kamalakar (2005) conducted A field experiment on the "Effect of molybdenum and boron application on their uptake and yield of cauliflower grown on Alfisolsof Southern Telangana Zone" found that combined application of molybdenumand boron at 0.50 kg Mo ha-1 + 2.0 kg boron ha-1 recorded significantly higher number of leaves per plant, curd diameter, curd weight per plant, dry matter yield of plant (leaf + stem), curd and whole plant, curd weight per plant, curd yield, molybdenum and boron contents and their uptake by plant, curd and whole plant. This treatment was on par with 0.75 kg Mo/ha 1.0 kg B/ha and 0.75 kg Mo/ha 2.0 kg B/ha. The curd yield and the molybdenum and boron uptake by whole plant with combined application of 0.5 kg Mo/ha and 2.0 kg B/ha were 19.0 t/ha.
3.55 g ha-1 and 121.19 g ha-1, respectively and this treatment was highly significant and best among all the combination treatments.

Chattopadhyay and Mukhopadhyay (2003) stated that application of molybdenum at 0.4 kg per hectare resulted in getting the highest curd yield of 290.16 quintal per hectare when compared to 252. 23 quintal per hectare obtained in control.

Sharma *et al.* (2002) observed the interaction effects of Boron and molybdenum were significant for seed yield per plant. A combination of 25 kg borax and 1.5 kg ammonium molybdate per hectare through soil application recorded highest seed yield.

Sanjay and Chaudhary (2002) conducted a field experiment to study the effects of molybdenum (0.5 and 1 kg sodium molybdate/ha) and boron (10 and 20 kg borax/ha), applied alone or in combination with 25 t farmyard manure (FYM)/ha, on the yield and yield components of cauliflower cv. Pusa Snowball-1 were determined in a field experiment conducted in Kullu, Himachal Pradesh, India from October to March of 1995-97. Molybdenum and boron application significantly increased curd diameter, weight and yield in the absence of FYM. Boron at 10 kg/ha and molybdenum at 0.5 kg/ha increased the yield by 32 and 14%, respectively. Application of FYM in addition to 100% recommended NPK enhanced the yield of cauliflower by about 27% compared to application of NPK alone.

Sharma *et al.* (2002) Application of Molybdenum has significant effect on the marketable card yield. Application of sodium molybdate at 250 grams, 500 gram and 1000 gram per hectare produce more yields of 213.7, 216.4 and 203.7 quintal per hectare respectively when compared to to control in which more yield (33.7 quintal/ ha) was recorded.

CHAPTER III

MATERIALS AND METHODS

This chapter includes major information regarding materials and methods that were used in conducting the experiment. It consists of a short description of locations of the experimental site, characteristics of soil, climate, materials of the investigation, layout and design of the experiment, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural operations, harvesting, data collection procedure and statistical analysis etc. The details of the experiment are described below.

3.1 Experimental site

The experiment was conducted during the rabi season (October 2019 to February 2020) at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka-1207. The location of the experimental site was at 23^0 75′ North latitude and 90^0 34′ East longitude with an elevation of 8.45 meter from sea level.

3.2 Characteristics of Soil

The soil of the experimental field belongs to the Tejgaon series under the Madhupur Tract (AEZ-28) and the General Soil Type is Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the study. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka for some important physical and chemical properties. The soil was having a texture of sandy loam with pH and organic matter capacity 5.6 and 0.78%, respectively and the the soil composed of 27% sand, 43% silt, 30% clay. Details descriptions of the characteristics of soil are presented in Appendix III.

3.3 Climatic condition of the experimental area

Experimental site was located in the subtropical monsoon climatic zone, set aparted by heavy rainfall during the months from April to September and scant of rainfall during the rest of the year. Plenty of sunshine and moderately low temperature prevails during October to March which is generally preferred for vegetable cultivation. Details of the meteorological data during the period of the experiment was collected from the Bangladesh Meteorological Department, Agargaon, Dhaka-1207 and presented in Appendix II.

3.4 Plant materials used in the experiment

BARI Fulkopi-1(Rupa) developed by Bangladesh Agricultural Research Institute was used in the experiment. Seed of BARI Fulkopi-1(Rupa) was collected from Bangladesh Agricultural Research Institute (BARI), Gazipur.

3.5 Seedbed preparation

Seedbed preparation for raising healthy seedlings was an important task before starting the field research work. In the farm a suitable place was selected for the seedbed and the size of the seedbed was 3 m×1 m. For making seedbed, the soil was well ploughed and converted into loose friable and dried masses to obtain good tilt. Weeds, stubbles and dead roots were removed from the seedbed. The soil of seedbed was treated by Sevin 50WP @ 5 kg/ha to protect the young plants from the attack of mole crickets, ants and cutworms.

3.6 Treatment of seed

Before sowing seeds in the seedbed Provax 200WP @ 3g/1kg seeds was applied to treat the seeds to protect some seed borne diseases such as leaf spot, blight, anthracnose, etc.

3.7 Seed sowing

Sowing of seeds was done on 16th October, 2019 in the seedbed. It was done thinly in lines spaced at 5 cm distance. Seeds were sown at a depth of 2 cm and covered with a fine layer of soil and then light irrigation was done by water can. Then the beds were covered with dry straw to maintain required temperature and moisture. The cover of dry straw was removed immediately after emergence of seed sprout. To protect the young seedlings from scorching sunshine and rain, a bamboo mat was provided to shade when the seeds were germinated. Seeds were completely germinated within 5-6 days after sowing.

3.8 Raising of seedlings

Watering and weeding were done several times. No chemical fertilizers were applied for rising of seedlings. Seedlings were not attacked by any kind of insect or disease. Healthy and 25 days old seedlings were transplanted into the experimental field on 10th November 2020.

3.9 Layout and design

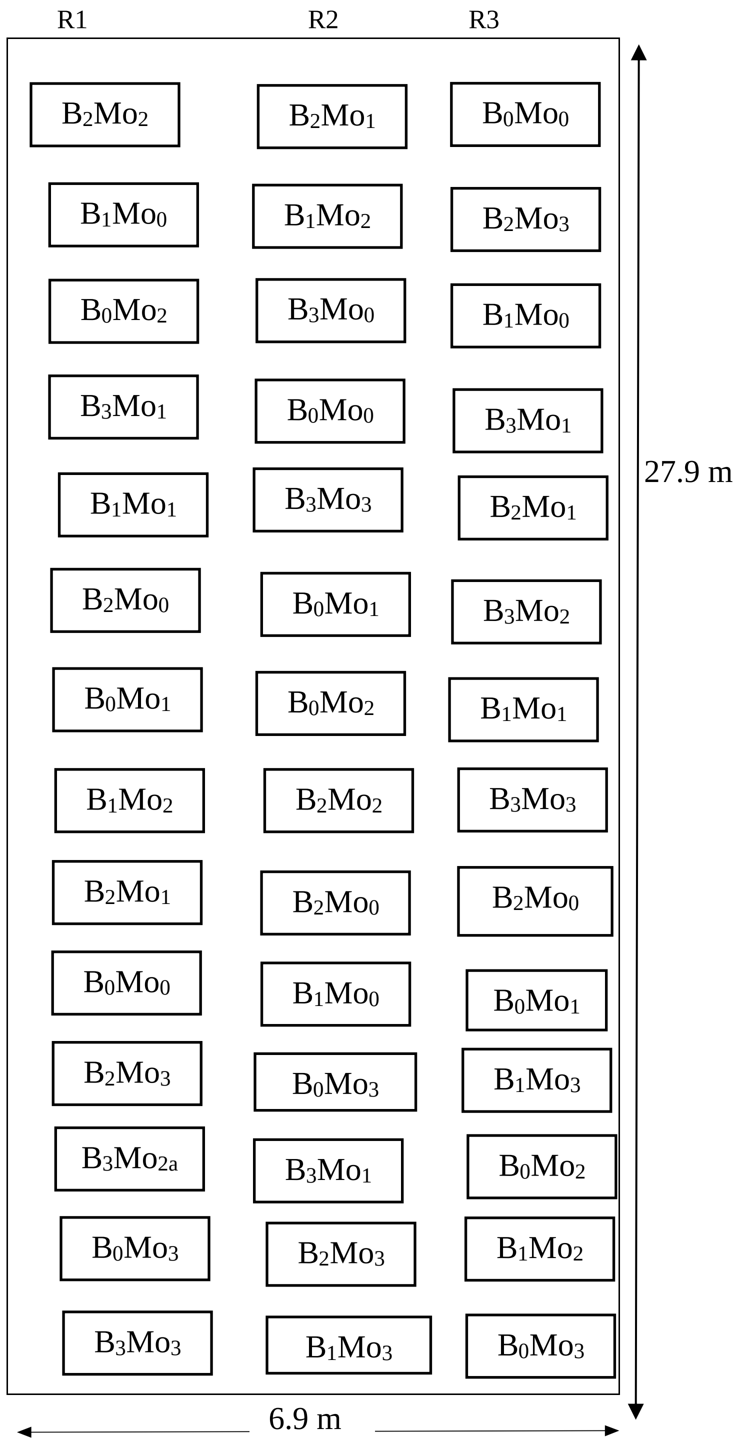
The field experiment was conducted by Randomized Complete Block Design (RCBD) with three replications. Two factors were used in the experiment viz. four levels of boron and four levels of Molybdenum. The experimental plot was first divided into three blocks. Each block consisted of 16 plots. Thus, the total number of plots was 48. Different combinations of boron and Molybdenum were assigned randomly to each plot as per design of the experiment. The size of a unit plot was 1.2 m × 1.6 m. A distance of 0.5 m between the plots and 0.5 m between the blocks were kept. Thus, the total area of the experiment was 92.16 m^2.

3.10 Treatment of the experiment

Factor A: Four levels of boron	Factor B: Four levels of Molybdenum
B_0: 0 (Control) kg/ha	Mo_0: 0 (Control) kg/ha
B_1: 0.5 kg/ha	Mo_1: 0.25 kg/ha
B_2:1 kg/ha	Mo_2: 0.50 kg/ha
B_3: 1.5 kg/ha	Mo_3: 0.75 kg/ha

The experiment consisted of two factors. Details were presented below:

There were 16 treatments combinations such as: B_0Mo_0, B_0 Mo_1, B_0Mo_2, B_0Mo_3, B_1Mo_0, B_1Mo_1, B_1Mo_2, B_1Mo_3, B_2Mo_0, B_2Mo_1, B_2Mo_2, B_2Mo_3, B_3Mo_0, B_3Mo_1, B_3Mo_2, B_3Mo_3. The treatment combination was done randomly. Here, B_0 and Mo_0 treatments were control that means no boron and molybdenum was used where in B_3 and Mo_3 treatments 1.5 kg/ha boron and 0.75kg/ha molybdenum was used. Here, Boric acid (H_3BO_3) used as a source of boron that contains 17.48% boron and Ammonium molybdate $(NH_4)_6Mo_7O_{24}$ used as a source of molybdenum that contains 54% molybdenum.



Factor A: Boron (kg/ha)

B_0: 0 (Control)
B_1: 0.5
B_2:1
B_3: 1.5

Factor B: Molybdenum (kg/ha)

Mo_0: 0 (Control)
Mo_1: 0.25
Mo_2: 0.50
Mo_3: 0.75

Plot size: 1.2 m × 1.6 m
Spacing: 50 cm × 50 cm
Spacing between replication: 0.5 cm
Spacing between plots: 0.5 cm

Figure 1. Layout of experiment

3.11 Cultivation procedure

3.11.1 Land preparation

The selected plot of the experiment was opened in the 2^{nd} week of October 2019 with a power tiller, and left exposed to the sun for a week. Subsequently cross ploughing was done five times with a country plough followed by laddering to make the land suitable for transplanting the seedlings. All weeds, stubbles and residues were eliminated from the field. Finally, a good tilt was achieved. The experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in Figure 1. The soil was treated with insecticides (Cinocarb 3G @ 4 kg/ha) at the time of final land preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

3.11.2 Application of manure and fertilizer

Manure and fertilizers that were applied presented in Table 1. The total amount of cowdung, TSP, Gypsum and half of the MP was applied to the plot during final land preparation as basal dose. Boron was applied as boric acid (16% B) and Molybdenum as Ammonium molybdate (54% Mo) also as basal treatment. Urea was applied in three equal installments at 15, 30 and 45 days after transplanting in ring method. Rest half of the MP was applied in two equal installments at 15 and 30 days after transplanting in ring method.

Table 1. Dose and Date of fertilizer and manure applications

Fertilizer and manure	Dose per hectare	Application (%)			
		Basal	15 DAT	30 DAT	45 DAT
Cow dung	10 ton	10 ton			
Urea	150		50	50	50
TSP	150	150			
MOP	120	60	30	30	
Gypsum	100	100			
Boric acid	As per treatment				
Ammonium molybdate	As per treatment				

(Source: Fertilizer Recommendation Guide)

3.11.3 Transplanting

The entire seedbed was irrigated before uprooting the seedlings to minimize the damage of roots. During the uprooting, care was taken so that root damage become minimum and some soil remained with the roots. 25 days old healthy seedlings were transplanted at the spacing of 60 cm × 40 cm in the experimental plots on 10^{th} November 2019. Thus the 8 plants were accommodated in each unit plot. In the afternoon, planting was done. Light irrigation was given immediately after transplanting around each seedling for their better establishment. To protect the transplanted seedlings from scorching sunlight, shading was done for five dayswith the help of transparent polythene, watering was done up to five days until they became capable of establishing on their own root system.

3.12 Intercultural operations

3.12.1 Gap filling

Some seedlings were damaged after transplanting and gap filling was carried out with new seedlings from the seed bed.

3.12.2 Weeding

The plants were kept under careful observation. Significant number of weeds were found in the control treatment. Weeding was done three times in these plots. At 10, 30 and 40 DAT weeding was done followed by irrigation in the plots considering the optimum time for removal weed.

3.12.3 Spading

For proper growth and development, soils of each plot were pulverized by spade for easy aeration and it was done after each irrigation.

3.12.4 Irrigation

Just after transplanting of seedlings light irrigation was done. A week after transplanting the requirement of irrigation was realized through visual estimation. When the plants of a plot had shown the wilting symptoms the plots were irrigated on the same day with a hosepipe until the entire plot was properly wet.

3.12.5 Earthing up

Earthing up was done by taking the soil from the space between the rows.

3.12.6 Insects and disease control

Very few plants were damaged by mole crickets and cut worms after the seedlings were transplanted in the experimental plots. Sevin 80WP was dusted to the soil before irrigation to control these insects. Bird pests like nightingale (bulbuli) were seen visiting the cauliflower field very frequently. The nightingale visited the fields from 8 to 11 a.m. and 4 to 6 p.m. The birds were found to puncture the soft leaves and initiating curd and were controlled by striking of a metallic container.

(a)

b

Plate 1. (a) Raising of seedling in the seedbed and (b) Data collection in field

3.13 Harvesting

According to maturity indices, main curds were harvested at different dates. When the plants formed compact curd, main curds were harvested. Harvesting was started on 1st week of January, 2020 and was completed on 1st week of February, 2020. The curds were harvested with 20 cm of stem that was attached with the sprouts.

Plate 2. Harvesting of cauliflower

3.14 Detailed of data collection procedures

The data of the following characters were recorded from five plants randomly selected from each plot, except yield of curds, which was recorded plot wise.

3.14.1 Plant height

The height of the plant was measured from base to the tip of the longest leaf at 20, 40 and 60 days after transplanting (DAT). A meter scale was used to measure plant height of the plant and expressed in centimeter (cm).

3.14.2 Number of leaves per plant

The number of leaves per plant excluding the small leaves, which produced by axillary shoots was counted at 20, 40 and 60 days after transplanting.

3.14.3 Leaf length

The distance from the base of the petiole to the tip of the leaf was considered as length of leaf. It was measured also at 20, 40 and 60 DAT. A meter scale was used to measure the length of the large leaves and expressed in centimeter (cm).

3.14.4 Leaf breadth

The large leaf breadth was measured on 20, 40 and 60 DAT. A meter scale was used to measure the breadth of the large leaves and expressed in centimeter (cm).

3.14.5 Diameter of stem

The diameter of stem was measured at the point where the central curd was cut off. The diameter of stem was recorded by slide calipers.

3.14.6 Diameter of main curd

The diameter of curd was measured by using a meter 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).

3.14.7 Fresh weight of main curd

Fresh weight of the main curd per plant was recorded in gram excluding the weight of all secondary curds. It was measured by using a beam balance.

3.14.8 Dry matter of curd

Sample of 100 g curd was taken, cut into pieces and was dried under direct sunshine for 3 days and then was dried in an oven at 70^0 c for 72 hours before taking the dry weight till it was constant. The dry matter was calculated using following formula:

$$\% \text{ Dry matter of curd} = \frac{Dry\ weight\ of\ curd}{Fresh\ weightof\ curd} \times 100$$

3.14.9 Yield per plot

Calculation of the yield per plot was done by adding the weight of all the main curds produced in the respective plot. The yield of all plants in each unit plot was recorded and was expressed in kilogram (kg).

3.14.10 Yield per hectare

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

3.14.11 Yield per plot

Calculation of the yield per plot was done by adding the weight of all the main curds produced in the respective plot. The yield of all plants in each unit plot was recorded and was expressed in kilogram (kg).

3.14.12 Yield per hectare

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

3.15 Statistical analysis

The data obtained for different characters were statistically analyzed by using Statistics 10 software to find out the significance of the difference for boron and molybdenum on yield and yield contributing characters of cauliflower. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. Difference between treatments was assessed by Least Significant Difference (LSD) test at 0.05% level of significance (Gomez and Gomez, 1984).

3.16 Economic analysis

The cost of production was analyzed in order to find out the most economic combination different level of planting time and organic nutrient sources. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interests were calculated @ 14% in simple rate. Analyses were done according to the procedure of Alam *et al.* (1989). The benefit cost ratio (BCR) was calculated as follows:

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return per hectare (Tk.)}}{\text{Total cost of production per hectare (Tk.)}}$$

a

b

c

Plate 3. Pictorial presentation of (a) Irrigation by water can, (b) Curd initiation of cauliflower and (c) Harvesting and weighing

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to observe the effect of boron and molybdenum on growth and yield of cauliflower. The results of the present Study were presented in Tables 2-10 and Figures 2-15. The analyses of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendix IV-XI. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Plant height

Different levels of boron showed significant variation on the plant height of cauliflower at 20, 40 and 60 days after transplanting (fig. 2). At 20, 40 and 60 DAT the tallest plant (29.04, 43.84, 56.53 cm respectively) was recorded from B_2, B_3 and B_3 whereas at 20 and 40 DAT plant height was statistically similar to B_2 (28.08 cm), B_3(28.87 cm), and B_0, B_1, B_3 respectively. The shortest plant (7.03, 43.30 and 52.54 cm) at 20, 40 and 60 DAT was found from B_0 (control). Data revealed that different levels produced different height of plant and the tallest plant was found from B_2 (boron 1kg/ha). Ningawale *et al*. (2016) reported that application of boron increased the plant height of cauliflower and our finding is in agreement with their findings.

Data revealed that different levels of molybdenum also showed significant variation on the plant height of cauliflower at 20, 40 and 60 days after transplanting (fig.3). At 20, 40 and 60 DAT the tallest plant (29.00, 45.77 and 55.75 cm respectively) was recorded from Mo_2 whereas at 20 DAT plant height was statistically similar to Mo_1 (28.08 cm). The shortest plant (27.23, 43.40 and 52.59 cm) at 20, 40 and 60 DAT

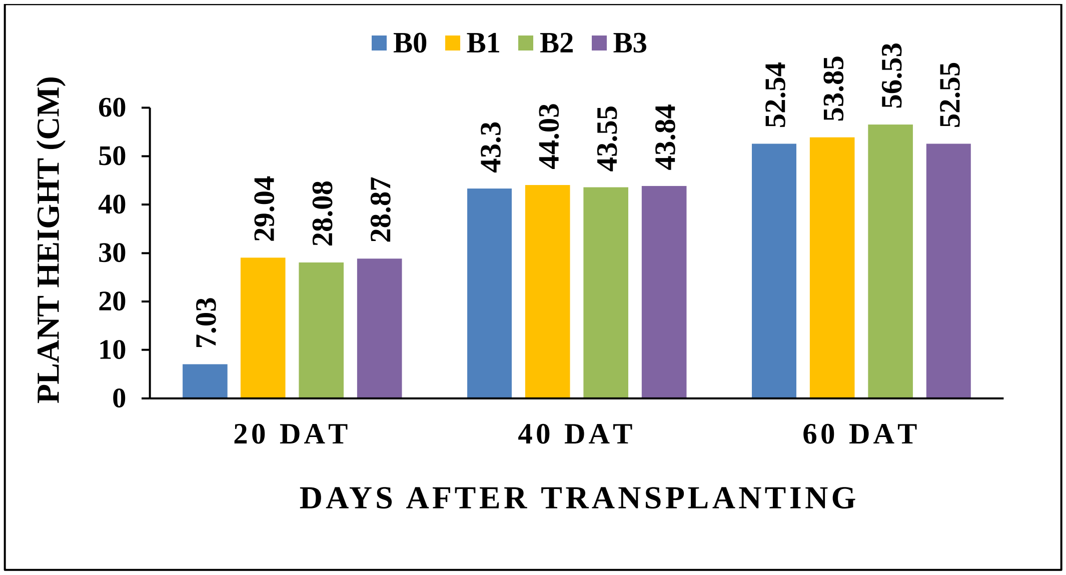


Figure 2. Effect of different levels of boron on plant height of cauliflower

Here, B_0: 0 kg/ha (Control), B_1: 0.5 kg/ha, B_2: 1 kg/ha, B_3: 1.5 kg/ha

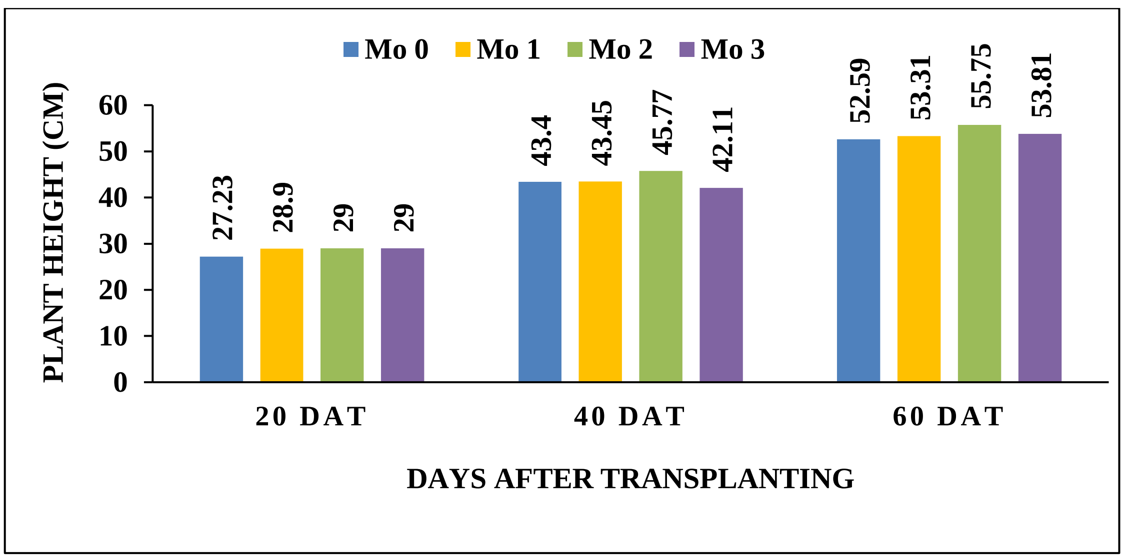


Figure 3. Effect of different levels of molybdenum on plant height ofcauliflower

Here, Mo0: 0 kg/ha (Control), Mo1: 0.25 kg/ha, Mo2: 0.50 kg/ha, Mo3: 0.75 kg/ha

Table 2. Combined effect of boron and molybdenum on plant height at different Days After Transplanting (DAT) of cauliflower

Treatments	Plant height (cm)		
	20 DAT	**40 DAT**	**60 DAT**
B_0Mo_0	25.11 f	42.06 de	50.50 f
B_0 Mo_1	28.11 b-e	41.58 ef	51.00 ef
B_0 Mo_2	27.93 b-e	46.08 ab	56.50 ab
B_0 Mo_3	26.96 d-f	43.50 b-e	52.17 d-f
B_1 Mo_0	29.38 ab	45.16 a-c	53.00 c-f
B_1 Mo_1	29.50 ab	44.57 a-e	53.27 c-f
B_1 Mo_2	30.26 a	44.56 a-e	55.33 a-c
B_1 Mo_3	27.01 c-f	38.79 f	53.80 b-e
B_2 Mo_0	26.46 ef	43.33 b-e	56.33 ab
B_2 Mo_1	28.28 a-e	43.33 b-e	56.66 ab
B_2 Mo_2	29.01 ab	47.61 a	56.88 a
B_2 Mo_3	28.57 a-d	42.95 c-e	56.26 ab
B_3 Mo_0	27.96 b-e	43.05 b-e	50.57 f
B_3 Mo_1	29.68 ab	44.33 b-e	52.33 d-f
B_3 Mo_2	28.81 a-d	44.83 a-d	54.30 a-d
B_3 Mo_3	29.00 a-c	43.16 b-e	53.03 c-f
LSD $_{(0.05)}$	1.98	3.05	2.93
CV (%)	4.22	4.19	5.26

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability. Here, B_0: 0 kg/ha (Control), B_1: 0.5 kg/ha, B_2: 1 kg/ha, B_3:1.5 kg/ha, Mo_0: 0 kg/ha (Control), Mo_1:0.25 kg/ha, Mo_2: 0.50 kg/ha, Mo_3: 0.75 kg/ha.

was found from Mo_0 (control). Data revealed that different levels produced different height of plant and the tallest plant was found from Mo_2 (boron 0.50 kg/ha). The results are in close agreement with the findings of Sharma (2002) in cauliflower, who stated that the probable reasons for enhanced plant height and number of leaves, may be due to promoted effects of molybdenum on vegetative growth which ultimately leads to more photosynthetic activities.

Combined effect of different levels of boron and molybdenum showed significant differences on plant height of cauliflower at 20, 40 and 60 DAT (Table 2). At 20 DAT the tallest plant (30.26 cm) was recorded from B_1Mo_2 and the shortest plant (25.11 cm) was found in B_0Mo_0 which was statistically similar to B_2Mo_0 (26.46 cm). At 40 and 60 DAT the tallest plant (47.61 and 56.88 cm) was found in $B_2Mo_2$and the shortest plant (38.79 and 50.50 cm) was recorded from B_1Mo_3 and B_0Mo_0 respectively. The highest plant height was observed from B_2Mo_2 which was 56.88 cm, consequently the shortest plant was observed from B_0Mo_0 which was 50.50 cm. It was revealed that plant height increased with the increased in DAT and optimum level of boron ensured the tallest plant and excess amount causes decrease in plant height.

4.2 Number of leaves

Different levels of boron showed significant variation on number of leaves of cauliflower at 20, 40 and 60 days after transplanting (fig. 4). At 20 DAT the maximum number of leaf (11.75) was recorded from B_3 and it was statistically similar to B_1 (11.50) and B_2 (11.49) whereas minimum number of leaves was recorded from B_0 where mean value was 10.81. On the other hand, at 40 and 60 DAT the maximum number of leaf (17.41) and (21.59) was recorded from B_2 and it was statistically similar to B_1 (17.34) and B_3 (17.16) at 40 DAT and B_3 (21.21) 60 DAT respectively. In case of minimum number of leaves at 40 and 60 DAT was recorded from B_0 (16.08 and 19.12) respectively. Data revealed that different levels of boron showed different number of leaves and maximum number was found from B_2 (21.59) at boron 1kg/ha application. The results are in close agreement with the findings of Singh (2003) in cauliflower, who stated that the probable reasons for enhanced Borax applied at 5 kg/ha as soil treatment + 0.25% as foliar spray at 45 and 60 DAP resulted in the highest number of leaves per plant, leaf area, curd weight and curd width on vegetative growth which ultimately leads to more photosynthetic activities.

Number of leaves/plant at different stages was significant among the treatments. Significant variation was found after different levels of molybdenum application on number of leaves of cauliflower at 20, 40 and 60 days after transplanting (fig. 5). At 20, 40 and 60 DAT the maximum number of leaf (11.86, 17.49 and 21.01) was recorded from Mo_2 (0.5 kg/ha Mo) whereas minimum number of leaves was recordedfrom Mo_0 (11.20 and 17.14) at 20 and 40 DAT respectively and at 60 DAT minimumnumber of leaves was recorded from Mo_3 and mean value was 20.23. From the observation of the above data it was concluded that different levels of molybdenumshowed different number of leaves and maximum number was found from Mo_2 (21.01) at molybdenum 0.5 kg/ha application. The promotional effect on plant development of cauliflower plants may be due to the regulatory effects of molybdenum on plant development through largely functions in the enzyme systems of nitrogen fixation and nitrate reduction. The results were in harmony with the previous researchers Elkhatib (2009) on common bean soybean. Similar result was found from Sharma (2002) in cauliflower, who stated that the probable reasons for enhanced number of leaves, may be due to promote effects of molybdenum on vegetative growth which ultimately leads to more photosynthetic activities.

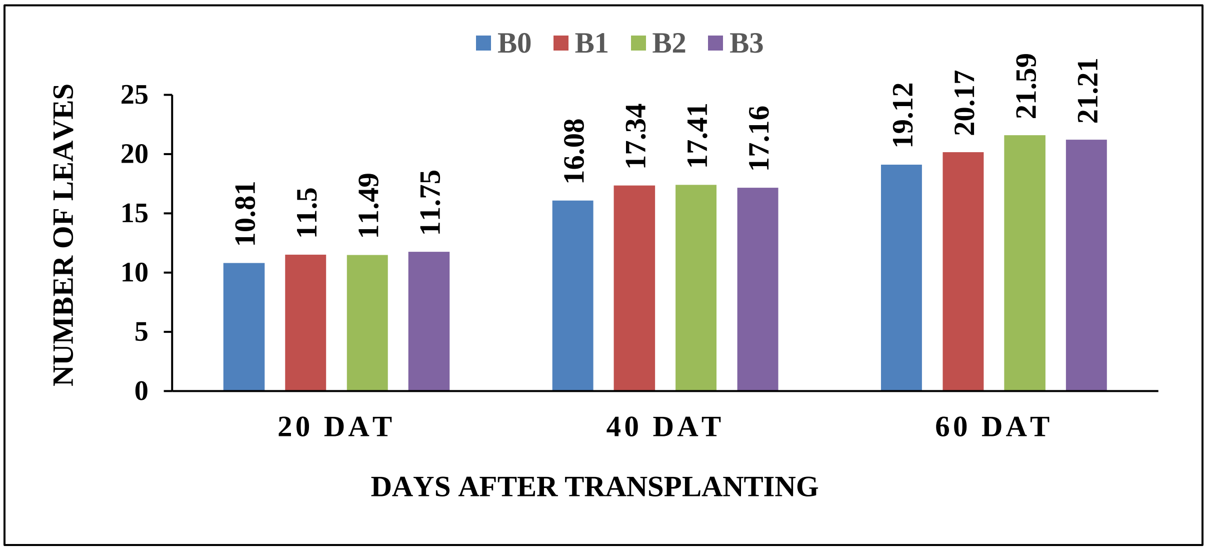


Figure 4. Effect of different levels of boron on number of leaves of cauliflower

Here, B_0: 0 kg/ha (Control), B_1: 0.5 kg/ha, B_2: 1 kg/ha, B_3: 1.5kg/ha

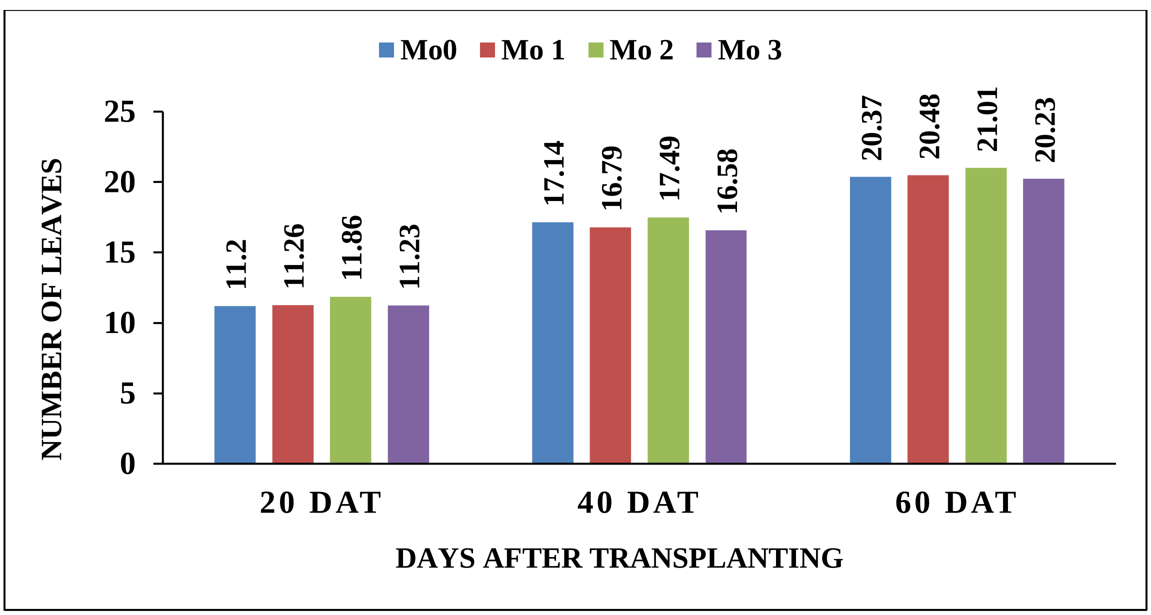


Figure 5. Effect of different levels of molybdenum on number of leaves ofcauliflower

Here, Mo_0: 0 kg/ha (Control), Mo_1:0.25 kg/ha, Mo_2: 0.50 kg/ha, Mo_3: 0.75 kg/ha

Combined effect of different levels of boron and molybdenum showed significant differences on number of leaves of cauliflower at 20, 40 and 60 DAT (table 3). At 20, 40 and 60 DAT the maximum number of leaf (12.49, 19.16 and 22.83) was recorded from B_2 Mo_2 whereas minimum number of leaves was recorded from B_0Mo_0 (10.50, 14.83 and 18.33) at 20, 40 and 60 DAT respectively. The maximum number of leaves was observed from B_2Mo_2 which was 22.83, consequently the minimum number of leaves was observed from B_0M_{O0} which was 18.33. It was revealed that number of leaves were increased with the increased in DAT and optimum level of boron and molybdenum ensured the maximum and excess amount causes decrease in number of leaves.

Table 3. Combined effect of boron and molybdenum on number of leaves at different Days After Transplanting (DAT) of cauliflower

Treatments	Number of leaves at		
	20 DAT	40 DAT	60 DAT
B_0Mo_0	10.50 d	14.83 g	18.33 h
B_0 Mo_1	11.00 b-d	16.16 ef	18.83 gh
B_0 Mo_2	11.16 b-d	17.00 de	20.16 c-g
B_0 Mo_3	10.59 d	16.35 d-f	19.16 fg
B_1 Mo_0	11.33 a-d	17.59 b-d	20.67 b-e
B_1 Mo_1	11.22 b-d	16.50 d-f	20.05 d-g
B_1 Mo_2	12.11 ab	18.47 a-c	20.22 b-f
B_1 Mo_3	11.33 a-d	16.80 d-f	19.75 e-g
B_2 Mo_0	11.33 a-d	17.00 de	21.33 b-d
B_2 Mo_1	10.83 cd	17.16 de	21.55 ab
B_2 Mo_2	12.49 a	19.16 a	22.83 a
B_2 Mo_3	11.33 a-d	16.66 d-f	20.66 b-e
B_3 Mo_0	11.66 a-d	18.83 ab	21.16 b-d
B_3 Mo_1	12.00 a-c	17.333 c-e	21.50 a-c
B_3 Mo_2	11.66 a-d	15.66 fg	20.83 b-e
B_3 Mo_3	11.66 a-d	16.49 d-f	21.33 b-d
$LSD_{(0.05)}$	1.17	1.29	1.35
CV (%)	6.18	5.56	4.93

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability. Here, B_0: 0 kg/ha (Control), B_1: 0.5 kg/ha, B_2:1 kg/ha, B_3:1.5 kg/ha, Mo_0: 0 kg/ha (Control), Mo_1:0.25 kg/ha, Mo_2: 0.50 kg/ha, Mo_3: 0.75 kg/ha.

4.3 Leaf length

Boron level had a significant influence on the length of leaves of cauliflower plants at 20, 40 and 60 DAT (Fig. 6). At 20 DAT, leaf length ranged from 18.01 cm to 18.77 cm and it was not significant the longest leaf (18.77) was recorded from B_2 which was statistically similar to other treatments. On the other hand, at 40 and 60 DAT the longest leaf length (33.61) and (43.73) was recorded from B_2 and it was statistically similar to B_3 (33.28) and B_3 (42.82) at 40 and 60 DAT respectively. In case of shortest leaf length at 40 and 60 DAT was recorded from B_0 (31.69 and 40.02) respectively. Data revealed that different levels of boron showed difference in the leaf length of cauliflower and longest length was found from B_2 (43.73) at boron 1kg/ha application. The results are in close agreement with the findings of Singh (2003) in cauliflower, who stated that the probable reasons for increase boron application resulted in the highest number of leaves per plant, leaf area, curd weight and curd width on vegetative growth which ultimately leads to more photosynthetic activities.

Molybdenum level had a significant influence on the length of leaves of cauliflower plants at 20, 40 and 60 DAT (Fig. 7). At 20, 40 and 60 DAT, leaf length ranged from18.33 cm to 43.98 cm and the longest leaf (18.78, 34.29 and 43.98) was recorded from Mo_2 whereas the shortest length (18.33, 31.57 and 40.73 cm) was from Mo_0, Mo_3 and Mo_3 at 20, 40 and 60 DAT respectively. Different levels of molybdenum showed difference in the leaf length of cauliflower and longest length was found from Mo_2 (43.98) at molybdenum 0.5 kg /ha application. Kumar *et al.* (2002), Prasad and Yadav (2003), Singh (2003)and Kumar (2004; 2005).

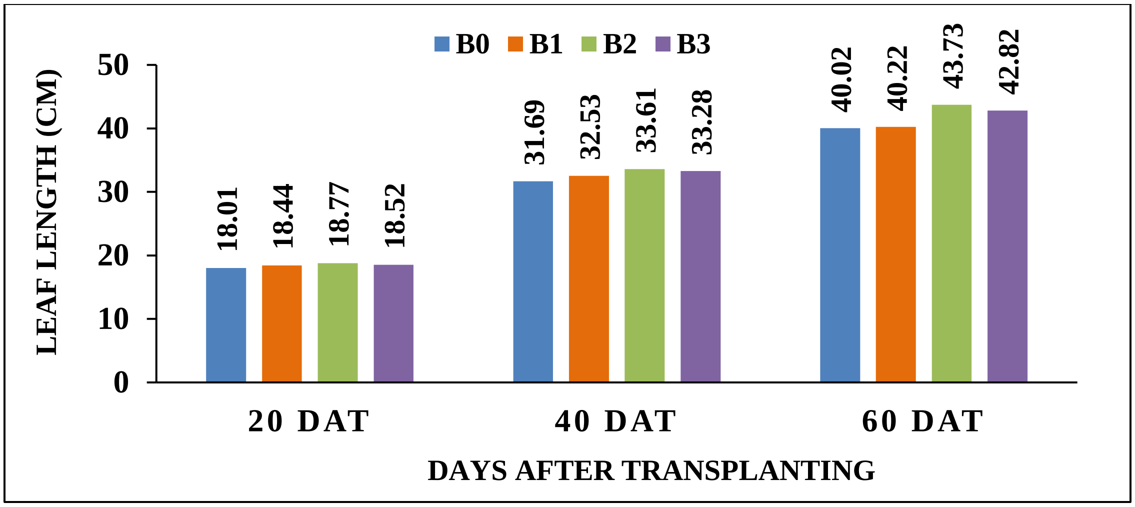


Figure 6. Effect of different levels of boron on leaf length of cauliflower

Here, B_0: 0 kg/ha (Control), B_1: 0.5 kg/ha, B_2: 1 kg/ha, B_3: 1.5kg/ha

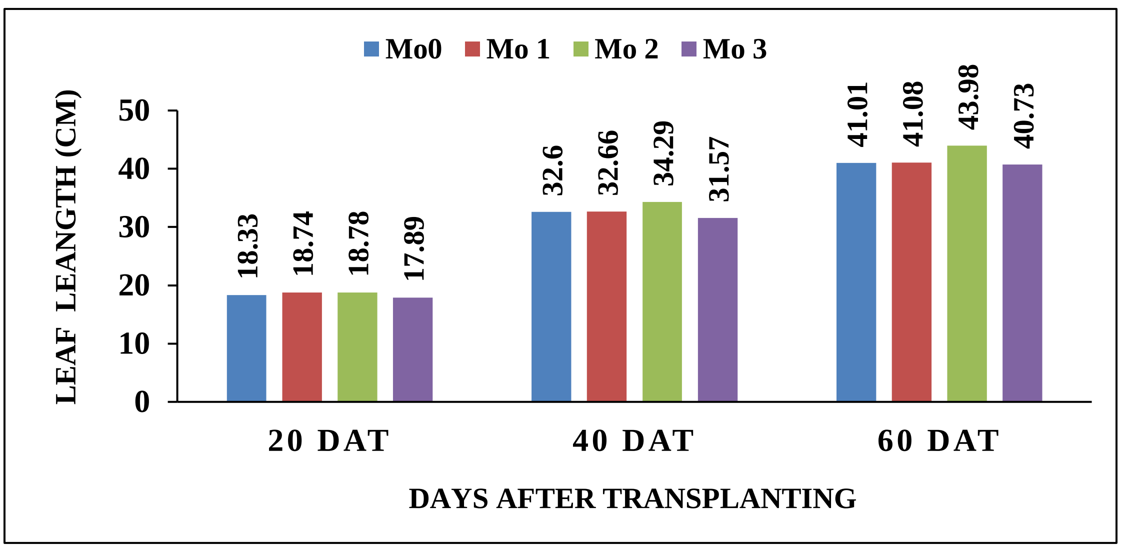


Figure 7. Effect of different levels of molybdenum on leaf length ofcauliflower

Here, Mo_0: 0 kg/ha (Control), Mo_1:0.25 kg/ha, Mo_2: 0.50 kg/ha, Mo_3: 0.75 kg/h

Combined effect of different levels of boron and molybdenum showed significant differences on leaf length of cauliflower at 20, 40 and 60 DAT (table 4). At 20 DATthe longest leaf length (19.53) was recorded from B_2Mo_2 whereas shortest leaf length was recorded from B_0Mo_0 (16.53). At 40 DAT the longest leaf length (35.16) was recorded from B_1Mo_2 whereas shortest leaf length was recorded from B_0Mo_1 (29.15). At 60 DAT the longest leaf length (45.30) was recorded from B_3 andMo_2 whereas shortest leaf length was recorded from B_0 and Mo_0 (37.83).

Table 4. Combined effect of boron and molybdenum on leaf length at different Days After Transplanting (DAT) of cauliflower

Treatments	Leaf length at (cm)		
	20 DAT	**40 DAT**	**60 DAT**
B_0Mo_0	16.53 d	30.75 de	37.83 g
B_0 Mo_1	19.13 a-c	29.15 e	39.21 e-g
B_0 Mo_2	18.15 a-d	35.03 ab	43.50 ab
B_0 Mo_3	18.21 a-d	31.83 cd	39.54 d-g
B_1 Mo_0	19.25 ab	32.63 b-d	39.56 d-g
B_1 Mo_1	17.69 b-d	33.35 a-c	40.05 c-g
B_1 Mo_2	19.35 ab	35.16 a	42.44 a-d
B_1 Mo_3	17.48 cd	28.98 e	38.91 fg
B_2 Mo_0	18.80 a-c	33.29 a-c	44.70 ab
B_2 Mo_1	18.31 a-c	34.71 ab	43.23 a-c
B_2 Mo_2	19.53 a	33.58 a-c	44.69 ab
B_2 Mo_3	18.43 a-c	32.86 a-d	41.69 a-e
B_3 Mo_0	18.75 a-c	33.73 a-c	42.00 b-f
B_3 Mo_1	19.81 a	33.41 a-c	41.83 b-f
B_3 Mo_2	18.08 a-d	33.39 a-c	45.30 a
B_3 Mo_3	17.433 cd	32.60 b-d	42.16 a-e
$LSD_{(0.05)}$	1.75	2.47	3.22
CV (%)	5.67	5.52	5.63

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability. Here, B_0: 0 kg/ha (Control), B_1: 0.5 kg/ha, B_2:1 kg/ha, B_3:1.5 kg/ha, Mo_0: 0 kg/ha (Control), Mo_1:0.25 kg/ha, Mo_2: 0.50 kg/ha, Mo_3: 0.75 kg/ha.

4.4 Leaf breadth

Leaf breadth differs significantly due to the different level of boron at 20, 40 and 60 DAT (Fig. 8). At 20, 40 and 60 DAT leaf breadth ranged from 7.87 cm to 21.20 cm. The largest leaf breadth (8.42, 15.58 and 21.20) was recorded from B_2 whereas the smallest leaf breadth (7.87, 13.75 and 19.37) was recorded from B_1, B_0 and B_0 respectively. Data revealed that different levels of boron showed difference in the leaf breadth of cauliflower and largest breadth was found from B_2 (21.20) at boron 1kg/ha application. Similar results have been reported by Kotur (1993; 1994), Kumar *et al.* (2002), Prasad and Yadav (2003), Singh (2003) and Kumar(2004; 2005).

Molybdenum level had a significant influence on the leaf breadth of cauliflower plants at 20, 40 and 60 DAT (Fig. 9). At 20, 40 and 60 DAT, leaf breadth ranged from 7.61 cm to 18.66 cm and the largest leaf breadth (8.92 and 16.00) was recorded from Mo_2 whereas the smallest breadth (7.61 and 13.79 cm) was observed from Mo_0. At 60 DAT the data showed no significant variation and the largest leaf breadth (20.95) was recorded from Mo_2 whereas the smallest breadth (18.66 cm) was observed from Mo_0. Different levels of molybdenumshowed difference in the leaf breadth of cauliflower and largest breadth was found from Mo_2 (20.95) at molybdenum 0.5 kg /ha application. Similar results have been reported by Prasad and Yadav (2003), Singh (2003) and Kumar (2004; 2005).

Combined effect of different levels of boron and molybdenum showed significant differences on leaf breadth of cauliflower at 20, 40 and 60 DAT (Table 5). At 20, 40 and 60 DAT the largest leaf breadth (9.33, 18.00 and 23.33) was recorded from $B_2 Mo_2$ whereas smallest breadth was recorded from B_0Mo_0 (7.50, 12.33 and 17.33). It was revealed that leaf breadth increased with the increased in DAT and optimum level of boron and molybdenum.

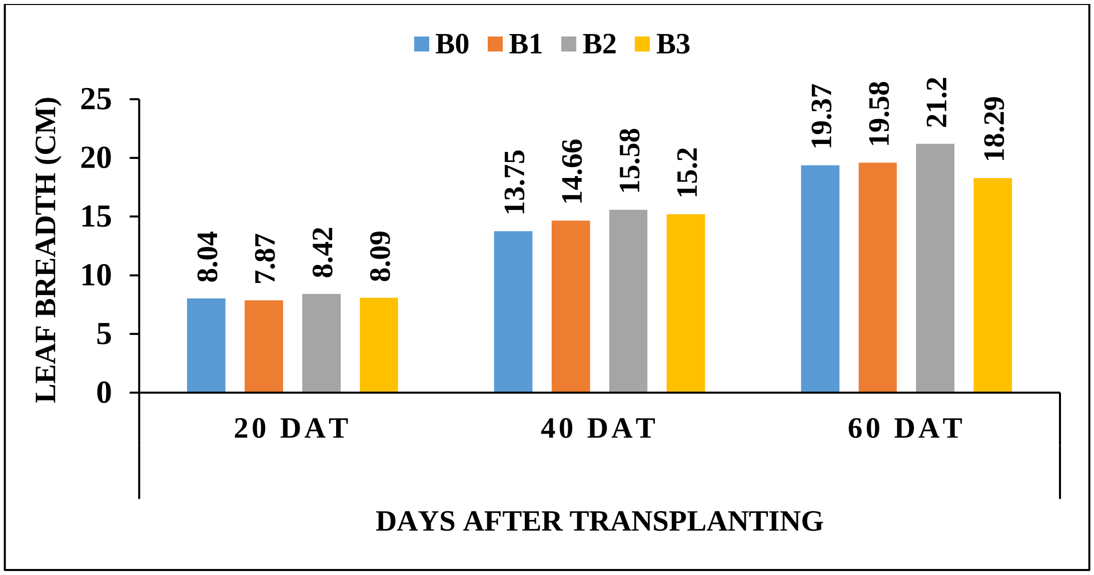


Figure 8. Effect of different levels boron on leaf breadth of cauliflower

Here, B_0: 0 kg/ha (Control), B_1: 0.5 kg/ha, B_2:1 kg/ha, B_3:1kg/ha

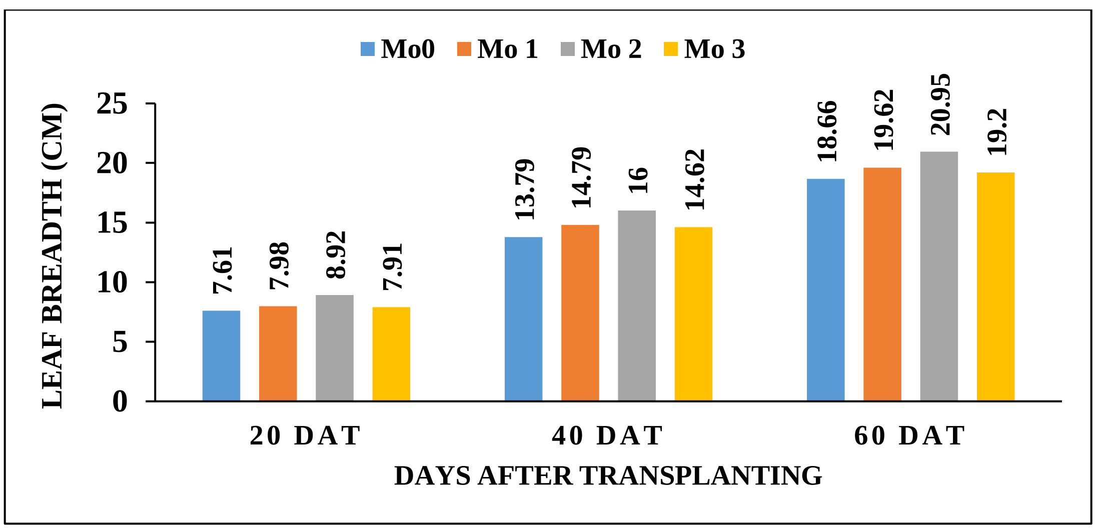


Figure 9. Effect of different levels molybdenum on leaf breadth of cauliflower

Here, Mo_0: 0 kg/ha (Control), Mo_1:0.25 kg/ha, Mo_2: 0.50 kg/ha, Mo: 0.75 kg/ha

Table 5. Combined effect of boron and molybdenum on leaf breadth at different Days After Transplanting (DAT) of cauliflower

Treatments	Leaf breadth at (cm)		
	20 DAT	40 DAT	60 DAT
B_0Mo_0	7.50 e	12.33 g	17.33 bc
$B_0 Mo_1$	8.00 c-e	14.00 d-f	20.00 a-c
$B_0 Mo_2$	9.00 ab	15.16 bc	21.33 a-c
$B_0 Mo_3$	7.68 de	13.50 f	18.83 a-c
$B_1 Mo_0$	7.50 e	13.83 ef	18.33 a-c
$B_1 Mo_1$	8.20 b-e	15.16 bc	19.33 a-c
$B_1 Mo_2$	8.50 a-d	16.00 b	22.33 ab
$B_1 Mo_3$	7.30 e	13.66 f	18.33 a-c
$B_2 Mo_0$	8.11 b-e	15.00 b-d	20.33 a-c
$B_2 Mo_1$	7.75 de	14.00 d-f	19.33 a-c
$B_2 Mo_2$	9.33 a	18.00 a	23.33 a
$B_2 Mo_3$	8.50 a-d	13.83 ef	21.83 a-c
$B_3 Mo_0$	7.33 e	14.00 d-f	18.66 a-c
$B_3 Mo_1$	8.00 c-e	16.00 b	19.83 a-c
$B_3 Mo_2$	8.86 a-c	14.83 c-e	16.83 c
$B_3 Mo_3$	8.12 b-e	17.50 a	17.833 bc
$LSD_{(0.05)}$	0.978	1.10	5.40
CV (%)	7.13	4.46	9.64

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability. Here, B_0: 0 (Control), B_1: 0.5 kg/ha, B_2:1 kg/ha, B_3:1kg/ha, Mo_0: 0 (Control), Mo_1:0.25 kg/ha, Mo_2: 0.50 kg/ha, Mo_3: 0.75 kg/ha.

4.5 Stem Diameter

Significant variation on different boron levels had been observed in the diameter of stem of cauliflower (Table 6). The diameter of stem ranged from 2.04 cm to 2.13 cm. The maximum diameter of stem (2.13) was recorded from the B_2 followed by other treatments. On the other hand, the minimum diameter of stem (2.04 cm) was found from B_0 (control or no application of boron).

The stem diameter of plant was found to be significantly influenced due to the application of Molybdenum at different levels of treatments (Table 6). As following the plant growth, the stem diameter of plant increased. The plants under Mo_2 gave maximum (2.17 cm) stem diameter whereas the lowest stem diameter (2.02 cm) was found from Mo_3 treatment.

The combined effect of boron and molybdenum levels was studied to be significant on diameter of stem (Table 7). It was ranged from 1.82 cm to 2.25 cm. The maximum diameter of stem (2.25 cm) was recorded from the treatment combination B_2Mo_1 and the minimum stem diameter (1.82 cm) was recorded from the treatment combination B_0 Mo_3.

4.6 Diameter of curd

Significant variation on different boron levels had been observed in the diameter of curd of cauliflower ((Table 6). The Diameter of curd ranged from 13.81 cm to 14.51 cm. The maximum diameter of curd (14.51) was recorded from the B_1 followed by other treatments. On the other hand, the minimum diameter of curd (13.81 cm) was found from B_0 (control or no application of boron). Ghosh and Hassan (1997) reported that application of Boron on the cauliflower cv. Early Kunwari significantly produced plants with the highest number of leaves/plant (27.2), the largest curds (1048 g) and the higher yield (524 q/ha).

Table 6. Effect of boron and molybdenum on stem diameter, curd diameter and fresh curd weight of cauliflower

Treatments	Stem Diameter (cm)	Curd diameter (cm)	fresh Curd wt. (gm)
B_0	2.04 b	13.81 b	625.25 a
B_1	2.10 ab	14.51 a	625.03 a
B_2	2.13 a	14.31 ab	637.25 a
B_3	2.07 ab	14.31 ab	606.86 a
$LSD_{(0.05)}$	0.07	0.60	35.50
CV (%)	5.03	5.15	6.83
Treatments	**Stem Diameter (cm)**	**Curd diameter (cm)**	**Curd fresh wt. (gm)**
Mo_0	2.07 b	14.17 a	608.06 b
Mo_1	2.08 b	13.87 a	614.61 b
Mo_2	2.17 a	14.46 a	656.22 a
Mo_3	2.02 b	14.12 a	615.50 b
$LSD_{(0.05)}$	0.07	0.60	35.50
CV (%)	5.03	5.15	6.83

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability. Here, B_0: 0(Control), B_1: 0.5 kg/ha, B_2:1 kg/ha, B_3:1.5 kg/ha, Mo_0: 0 (Control), Mo_1:0.25 kg/ha, Mo_2: 0.50 kg/ha, Mo_3: 0.75 kg/ha.

The diameter of curd of plant was not found to be significantly influenced due to the application of Molybdenum application at different levels of molybdenum treatments (Table 6). The plants under Mo_2 gave the maximum (14.46 cm) diameter ofcurd which was statistically similar to other treatments.

The combined effect of boron and molybdenum levels was studied to be significant on diameter of curd (Table 7). It was ranged from 15.25 cm to 13.10 cm. The maximum diameter of stem (15.25cm) was recorded from the treatment combination B_1 Mo_3 which was statistically similar to B_0 Mo_2 and mean value was 15.13. On the other hand, the minimum stem diameter (13.10 cm) was recorded from the treatment combination B_0 Mo_3.

4.7 Fresh curd weight

No Significant variation had been observed from the different boron levels in the curd fresh weight of cauliflower (Table 6). The curd fresh weight ranged from 606.86 g to 637.25 g. The maximum curd fresh weight (637.25) was recorded from the B_2 followed by other treatments. On the other hand, the minimum curd fresh weight (606.86 g) was found from B_3 (more than recommended dose of boron 1.5 kg/ha).

The curd fresh weight of plant was found to be significantly influenced due to the application of Molybdenum application at different levels of molybdenum treatments (Table 6). The plants under Mo_2 gave maximum (656.22 g) curd fresh weight followed by the other treatments and especially over control. These findings are in confirmation with findings of Kotur (1998), Singh *et al*. (2002), Prasadand Yadav (2003), Kumar (2004, 2005) and Mahmud *et al*. (2005). While, the control treatment showed minimum for the same character. This could be due to thelack of molybdenum.

Table 7. Combined effect of boron and molybdenum on stem diameter, curd diameter and fresh curd weight of cauliflower

Treatments	Stem diameter (cm)	Curd diameter (cm)	Curd fresh wt. (gm)
B_0Mo_0	2.07 b-d	13.68 cd	610.33 a-c
B_0 Mo_1	2.04 cd	13.34 cd	615.00 a-c
B_0 Mo_2	2.25 a	15.13 a	656.67 ab
B_0 Mo_3	1.82 e	13.10 d	619.00 a-c
B_1 Mo_0	2.15 a-c	14.05 a-d	607.05 a-c
B_1 Mo_1	2.03 cd	13.83 b-d	628.84 a-c
B_1 Mo_2	2.18 ab	14.91 ab	646.88 a-c
B_1 Mo_3	2.04 cd	15.25 a	617.34 a-c
B_2 Mo_0	2.05 b-d	14.50 a-c	633.50 a-c
B_2 Mo_1	2.25 a	14.23 a-d	627.83 a-c
B_2 Mo_2	2.15 a-c	14.14 a-d	670.67 a
B_2 Mo_3	2.05 b-d	14.38 a-c	670.06 a
B_3 Mo_0	2.02 cd	14.45 a-c	581.34 c
B_3 Mo_1	1.99 d	14.08 a-d	586.78 bc
B_3 Mo_2	2.09 b-d	13.68 cd	650.66 a-c
B_3 Mo_3	2.19 ab	13.76 b-d	608.66 a-c
$LSD_{(0.05)}$	0.15	1.22	71.00
CV (%)	5.03	5.15	6.83

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability. Here, B_0: 0 kg/ha (Control), B_1: 0.5 kg/ha, B_2:1 kg/ha, B_3:1.5 kg/ha, Mo_0: 0 kg/ha (Control), Mo_1:0.25 kg/ha, Mo_2: 0.50 kg/ha, Mo_3: 0.75 kg/ha.

The combined effect of boron and molybdenum levels was studied to be significant on fresh curd weight (Table 7). It was ranged from 581.34 g to 670.67 g. The maximum curd fresh weight (670.67 g) was recorded from the treatment combination B_2 Mo_2 which was statistically similar to B_2 Mo_3 and mean value was 670.67 g. On the other hand, the minimum curd fresh weight (581.34 g) was recorded from the treatment combination B_0 Mo_3.

4.8 Dry matter percentage of curd

Significant variation had been observed from the different boron levels in the dry matter percentage of curd of cauliflower (Table 8 and Fig. 10). The dry matter percentage of curd ranged from 8.90 to 10.11 g. The maximum dry matter percentage of curd (10.11) was recorded from the B_2 followed by other treatments. On the other hand, the minimum dry matter percentage of curd (8.90) was found from B_3 (more than recommended dose of boron 1.5 kg/ha). Thakur *et al.* (1991) reported that application of boron increased the dry matter content of cauliflower.

The dry matter percentage of curd of plant was found to be significantly influenced due to the application of Molybdenum application at different levels of molybdenum treatments (Table 9 and Fig. 11). The plants under Mo_2 gave maximum (10.60) dry matter percentage of curd followed by the other treatments. On the other hand, the minimum dry matter percentage of curd (8.24) was found from Mo_0.

The combined effect of boron and molybdenum levels was found to be significant on dry matter percentage of curd (Table 9). It was ranged from 7.93 to 11.13. The maximum dry matter percentage of curd (11.13) was recorded from the treatment combination B_1Mo_2 which was statistically similar to B_0 Mo_2 and mean value was 10.86. On the other hand, the minimum dry matter percentage of curd (7.93) was recorded from the treatment combination B_0Mo_3. This increase might be due to the collective effect of boron and molybdenum.

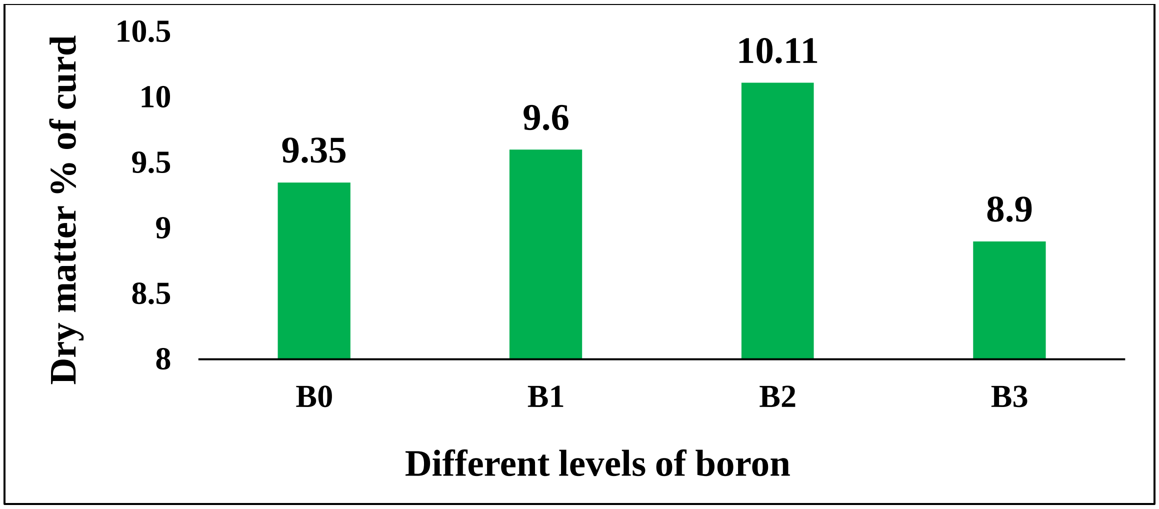


Figure 10. Effect of different levels boron on dry matter percentage of curd ofcauliflower

Here, B_0: 0 (Control), B_1: 0.5 kg/ha, B_2:1 kg/ha, B_3:1kg/ha

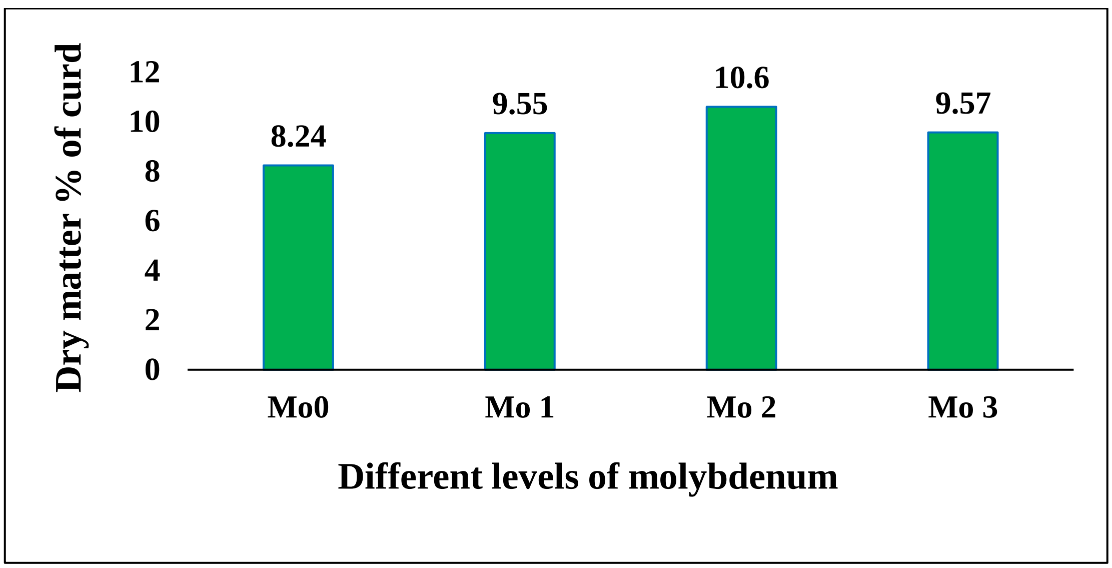


Figure11. Effect of different levels molybdenum on dry matter percentage of curd of cauliflower

Here, Mo_0: 0 (Control), Mo_1:0.25 kg/ha, Mo_2: 0.50 kg/ha, Mo_3: 0.75 kg/ha

4.9 Yield/plot

Significant variation had been observed from the different boron levels on yield/plot of cauliflower (Table 8 and Fig. 12). The yield/plot ranged from 4.75 kg to 5.09 kg. The highest yield/plot (5.09 kg) was recorded from the B_2 which was statistically identical to B_0 and B_1. On the other hand, the lowest yield /plot (4.75 kg) was found from B_3 (more than recommended dose of boron 1.5 kg/ha). Similar results have been reported by Thakur *et al*. (1991), Kumar and Choudhary (2002), Prasad and Yadav (2003), Sharma *et al.* (2002) and they reported that the application of boron increased the curd yield of cauliflower per plant as well as plot.

Different levels of molybdenum showed significant variation on yield/plot of cauliflower (Table 8 and Fig. 13). The plants under Mo2 gave highest (5.24 kg) yield/plot followed by the other treatments. On the other hand, the lowest yield /plot (4.86kg) was found from Mo_0. Similar results have been reported by Kumar and Choudhary (2002), Prasad and Yadav (2003), Sharma *et al*. (2002) and they reported that the application of molybdenum increased the curd yield of cauliflower per plant as well as plot.

The combined effect of boron and molybdenum levels was found to be significant on yield/plot of cauliflower (Table 9). It was ranged from 4.65 kg to 5.36 kg. The highest yield/plot (5.36 kg) was recorded from the treatment combination B_2Mo_2. On the other hand, the lowest yield /plot (4.65 kg) was recorded from the treatment combination B_3 and Mo_0.

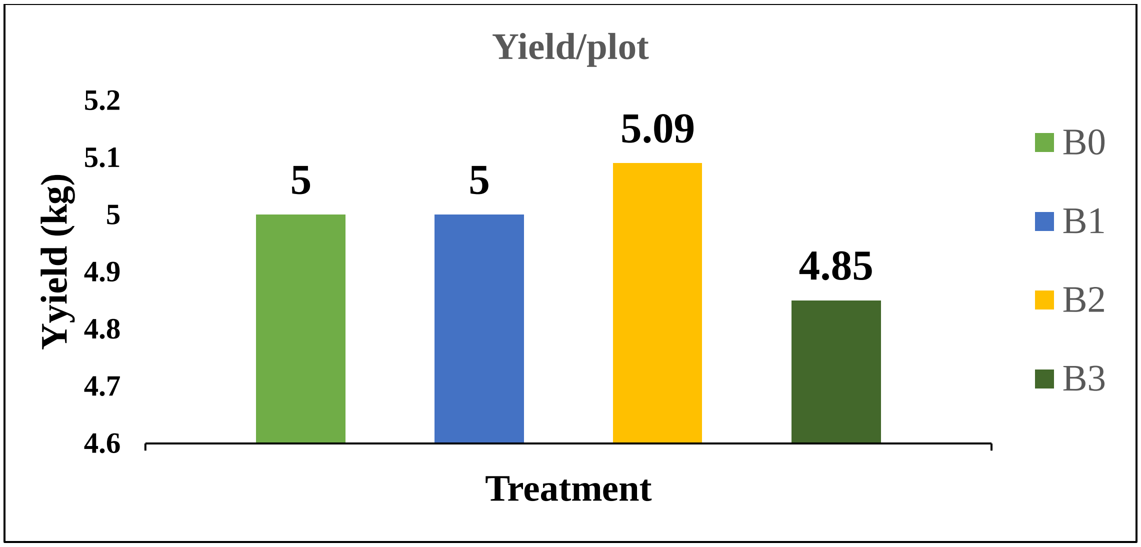


Figure 12. Effect of different levels of boron on yield per plot of cauliflower

Here, B_0: 0 (Control), B_1: 0.5 kg/ha, B_2: 1 kg/ha, B_3: 1.5 kg/ha

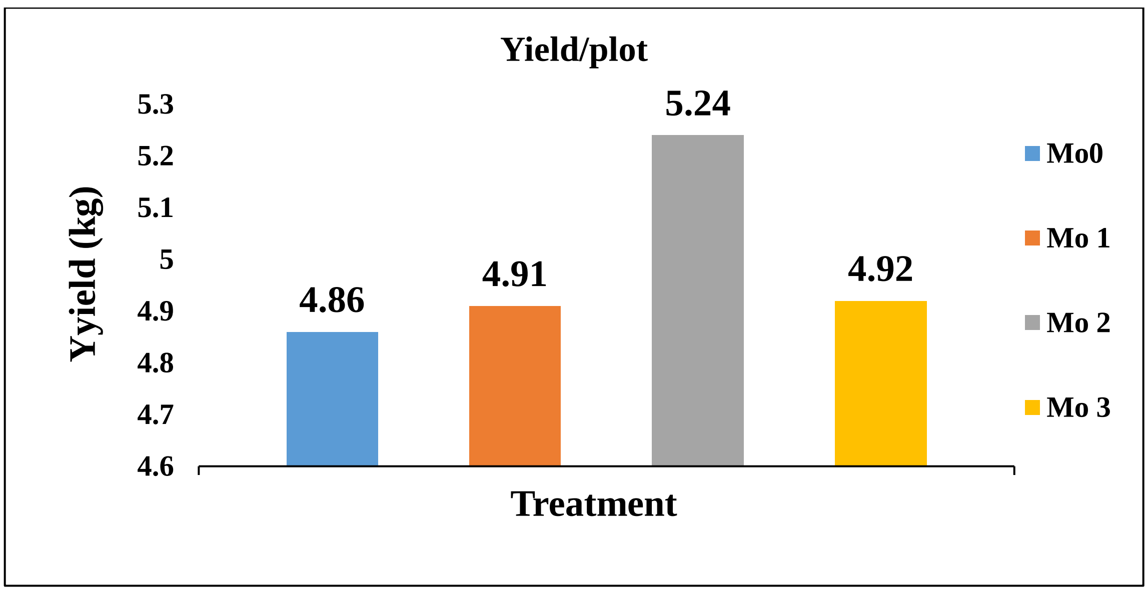


Figure 13. Effect of different levels of molybdenum on yield per plot of cauliflower

Here, Mo0: 0 kg/ha (Control), Mo1: 0.25 kg/ha, Mo2: 0.50 kg/ha, Mo3: 0.75 kg/ha

4.10 Yield/ha

Significant variation had been observed from the different boron levels on yield/plot of cauliflower (Table 8 and Fig. 12). The yield/plot ranged from4.75 kg to 5.09 kg. The highest yield/plot (5.09 kg) was recorded from the B2 which was statistically identical to B0 and B1. On the other hand, the lowest yield /plot (4.75 kg) was found from B3 (more than recommended dose of boron 1.5 kg/ha). Curd yield responded linearly to boron application in soil. Similar results have been reported by Islam et al. (2015) and Kumar and Choudhary (2002), they reported that the application of boron increased the curd yield of cauliflower and broccoli per plant as well as plot.

Different levels of molybdenum showed significant variation on yield/ha of cauliflower (Table 8 and Fig. 15). The plants under Mo_2 gave highest (27.34 ton) yield/ha followed by the other treatments. On the other hand, the lowest yield/ha (25.33 ton) was found from Mo_0. These findings are in confirmation with the findings of Singh (2003), Prasad and Yadav (2003), Mahmud et al. (2005).

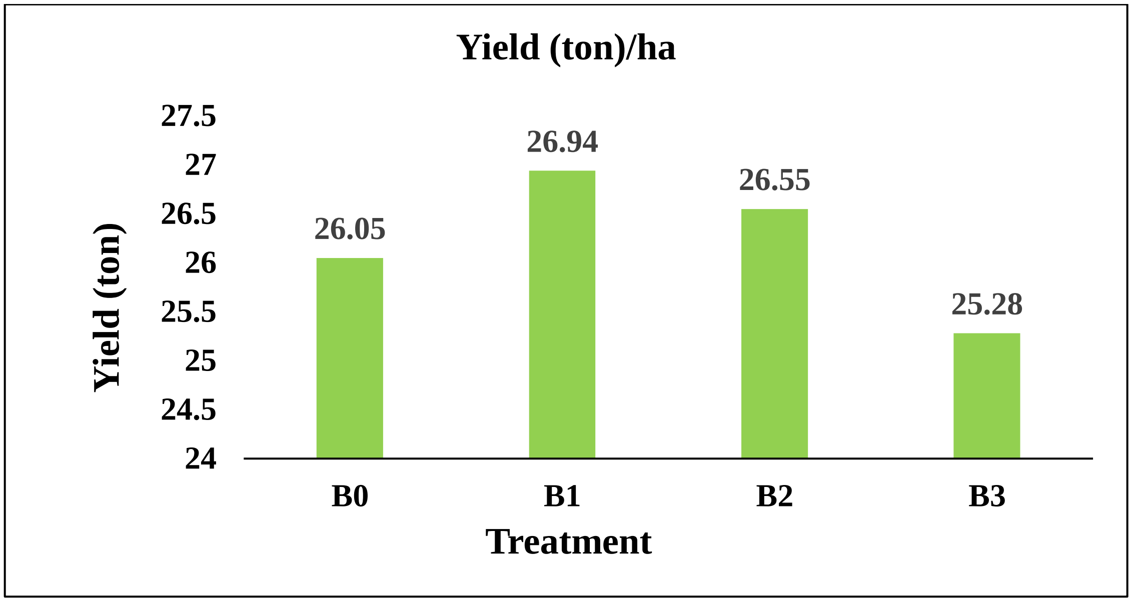


Figure 14. Effect of different levels of boron on yield per hectare of cauliflower

Here, B_0: 0 (Control), B_1: 0.5 kg/ha, B_2:1 kg/ha, B_3:1.5 kg/ha

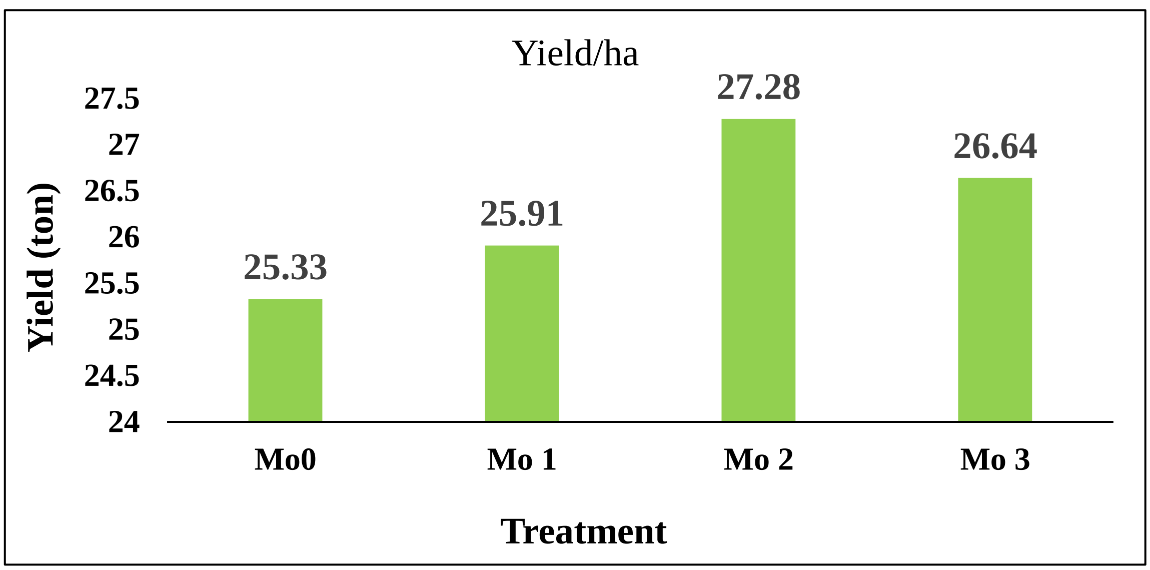


Figure 15. Effect of different levels of molybdenum on yield per hectare ofcauliflower

Here, Mo_0: 0 (Control), Mo_1:0.25 kg/ha, Mo_2: 0.50 kg/h, Mo_3: 0.75 kg/ha.

The combined effect of boron and molybdenum levels was found to be significant on yield/ha of cauliflower (Table 9). It was ranged from 24.22 ton to 27.94 ton. The highest yield/ha (27.94 ton) was recorded from the treatment combination B_2Mo_2. On the other hand, the lowest yield/ha (24.22 ton) was recorded from the treatment combination B_3Mo_0. The combined application of boron 1 kg/ha and molybdenum 0.5 kg/ha increased the total curd yield.

Table 8. Combined effect of boron and molybdenum on dry matter percentage of curd, yield/plot and yield/ha of cauliflower

Treatments	Dry matter percentage of curd	Yield (kg)/plot	Yield (ton)/ha
B_0Mo_0	7.93 h	4.88 a-c	25.42 a-c
B_0 Mo_1	9.53 cd	4.92 a-c	25.62 a-c
B_0 Mo_2	10.86 a	5.25 ab	27.35 ab
B_0 Mo_3	9.09 de	4.95 a-c	25.79 a-c
B_1 Mo_0	8.46 fg	4.85 a-c	25.29 a-c
B_1 Mo_1	9.65 c	5.03 a-c	26.20 a-c
B_1 Mo_2	10.91 a	5.17 a-c	26.95 a-c
B_1 Mo_3	9.36 cd	4.93 a-c	25.72 a-c
B_2 Mo_0	8.48 f-h	5.06 a-c	26.39 a-c
B_2 Mo_1	10.30 b	5.02 a-c	26.16 a-c
B_2 Mo_2	11.13 a	5.36 a	27.94 a
B_2 Mo_3	10.61 ab	4.93 a-c	25.70 a-c
B_3 Mo_0	8.18 gh	4.65 c	24.22 c
B_3 Mo_1	8.71 ef	4.69 bc	24.44 bc
B_3 Mo_2	9.49 cd	5.20 a-c	27.10 a-c
B_3 Mo_3	9.23 cd	4.87 a-c	25.35 a-c
$LSD_{(0.05)}$	0.52	0.57	2.96
CV (%)	4.14	6.83	6.83

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability. Here, B_0: 0 kg/ha (Control), B_1: 0.5 kg/ha, B_2:1 kg/ha, B_3:1.5 kg/ha, Mo_0: 0 (Control), Mo_1:0.25 kg/ha, Mo_2: 0.50 kg/ha, Mo_3: 0.75 kg/ha.

4.11 Performance on economic return

4.11.1 Cost of production

Due to effect of different treatment combinations showed major differences in terms of cost of production of cauliflower (Table 10). The highest cost of production of cauliflower (211133 Taka/ha) was obtained from B_3Mo_3. The lowest cost of production of cauliflower (209495Tk/ha) was obtained from B_0Mo_0.

4.11.2 Gross return

In case of gross return, different treatment combination showed considerable gross return of cauliflower production (Table 10). The highest gross return of cauliflower (419100 Taka/ha) was obtained from B_2Mo_2 and the second highest gross return of cauliflower production (410250 Taka/ha) was obtained from B_0Mo_2. The lowest gross return of cauliflower production (363300 Taka/ha) was obtained from B_3Mo_0.

4.11.3 Net return

Different treatment combinations showed large differences in terms of net return from Brussels sprouts production (Table 10). The highest net return of cauliflower production (208513 Taka/ha) was obtained from B_2Mo_2 and the second highest net return of cauliflower production (200100 Taka/ha) was obtained from B_0Mo_2. The lowest net return of cauliflower production (153150 Taka/ha) was obtained from B_3Mo_0.

4.11.4 Benefit cost ratio

Significant differences were showed by different treatment combinations on benefit cost ratio of cauliflower production (Table 10). Results indicated that the highest benefit cost ratio (1.99) was obtained from B_2Mo_2 and the second highest benefit cost ratio (1.95) was obtained from B_0Mo_2. The lowest benefit cost ratio (1.73) was obtained from B_3Mo_0. From economic point of view, it is apparent from the above results that the combination of B_2Mo_2 was more profitable treatment combination than rest of the combinations.

Table 9. Cost and return of cauliflower cultivation as influenced by boron and molybdenum

Treatments	Total cost of production	Yield/ha	Gross return (Tk./ha)	Net return (Tk./ha)	BCR
B_0Mo_0	209495	25.42	381300	171805	1.82
B_0Mo_1	209823	25.62	384300	174477	1.83
B_0Mo_2	210150	27.35	410250	200100	1.95
B_0Mo_3	210478	25.79	386850	176372	1.84
B_1Mo_0	209713	25.29	379350	169637	1.81
B_1Mo_1	210041	26.20	393000	182959	1.87
B_1Mo_2	210369	26.95	404250	193881	1.92
B_1Mo_3	210696	25.72	385800	175104	1.83
B_2Mo_0	209932	26.39	395850	185918	1.89
B_2Mo_1	210259	26.16	392400	182141	1.87
B_2Mo_2	210587	27.94	419100	208513	1.99
B_2Mo_3	210915	25.70	385500	174585	1.83
B_3Mo_0	210150	24.22	363300	153150	1.73
B_3Mo_1	210478	24.44	366600	156122	1.74
B_3Mo_2	210805	27.10	406500	195695	1.93
B_3Mo_3	211133	25.35	380250	169117	1.80

Here, B_0: 0 kg/ha (Control), B_1: 0.5 kg/ha, B_2:1 kg/ha, B_3:1.5 kg/ha, Mo_0: 0 kg/ha (Control), Mo_1:0.25 kg/ha, Mo_2: 0.50 kg/ha, Mo_3: 0.75 kg/ha.

Rate of cauliflower @ 15 Tk/kg

Gross return = Total yield (t/ha) × Price per kg × 1000

Net return = Gross return - Total cost of production

Benefit Cost Ratio (BCR) = Gross return/Total cost of production

CHAPTER V

SUMMARY AND CONCLUSION

Summary

The experiment was conducted during the rabi season (October 2019 to February 2020) at Horticulture Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh to study the effect of Boron and Molybdenum on the growth and yield of cauliflower. The variety of cauliflower was BARI Fulkopi-1(Rupa) and it was used as a test crop in the experiment. The experiment consisted of two factors, such as Factor A: Boron (4 levels) as B_0: 0 (Control) B_1: 0.5 kg/ha, B_2: 1 kg/ha, B_3: 1.5 kg/ha and Factor B: Molybdenum (4 levels) as Mo0: 0 (Control) Mo_1: 0.25 kg/ha, Mo_2: 0.50 kg/ha, Mo_3: 0.75 kg/ha. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

From the data it was discovered that all the parameters except leaf length at 20 DAT and curd fresh weight were significantly influenced by the different levels of boron. The B_2 (1 kg/ha) produced the highest plant height (56.53 cm), number of leaves per plant (21.59), leaf length (43.73 cm) and leaf breadth (21.20 cm) than other treatments at 60 DAT. The highest curd diameter (14.51 cm) was recorded from B_1 (0.5 kg/ha) where minimum was recorded from B_0 (control). The maximum dry matter percentage of curd (10.11), yield per plot (5.09 kg) and yield per hectare (26.65 t) were obtained from B_2 (1 kg/ha and the minimum yield per plot (4.75 kg) and yield per hectare (25.08 t) were obtained from B_0 treatment of boron.

Molybdenum significantly influenced the results of all parameters except leaf breadth at 60 DAT and curd diameter, the maximum height of plant (55.75 cm), number of leaves (21.01), leaf length (43.98 cm) and leaf breadth (20.95 cm) at 60 DAT was obtained from the treatment Mo_2 (0.50 kg/ha) which was higher than the other treatment. The maximum stem diameter (2.17 cm), curd fresh weight (656.22g) and percent dry matter of curd (10.60) were obtained from the treatment Mo_2

(0.50 kg/ha). The highest yield per plot (5.24 kg) and yield per hectare (27.34 t) were recorded from the treatment Mo_2 (0.50 kg/ha).

The combined effect of boron and molybdenum levels significantly influenced almost all the parameters of the cauliflower. The maximum height of plant (56.88 cm) and leaf breadth (23.33 cm) at 60 DAT was obtained from the treatment combinations of B_2Mo_2 (boron 1 kg/ha and molybdenum 0.50 kg/ha) where maximum number of leaf (22.83) and leaf length (45.30 cm) was observed from B_3Mo_2. The maximum stem diameter (2.25 cm), curd diameter (15.13 cm) was found from B_2Mo_1 and B_0Mo_2 respectively. The maximum curd fresh weight (670.67 g), dry matter percentage of curd (11.13) were obtained from the treatment combinations of B_2Mo_2. The highest yield per plot (5.36 kg) and yield per hectare (27.94 t) were recorded from the treatment combinations of B_2Mo_2. The lowest yield per plot (4.65 kg) and yield per hectare (24.22 t) were recorded B_3 Mo_0 treatment combinations.

From the economic point of view, in the different levels of molybdenum and boron applications the highest benefit cost ratio (1.99) was obtained from B_2Mo_2 and the lowest benefit cost ratio (1.51) was obtained from B_0Mo_2. From economic point of view, the combination of B_2Mo_2 was more profitable treatment combination than rest of the combinations.

Conclusions

1. Micronutrient combination B_2Mo_2 (boron 1 kg/ha and molybdenum 0.50 kg/ha) was more effective than control (B_0Mo_0).
2. Therefore, the results of the investigation suggest that the highest curd yield and good shape of cauliflower curd can be obtained in combined application of B 1.0 kg/ha with Mo 0.50 kg/ha.

CHAPTER VI

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APPENDICES

Appendix I. Map showing the experimental site under study.

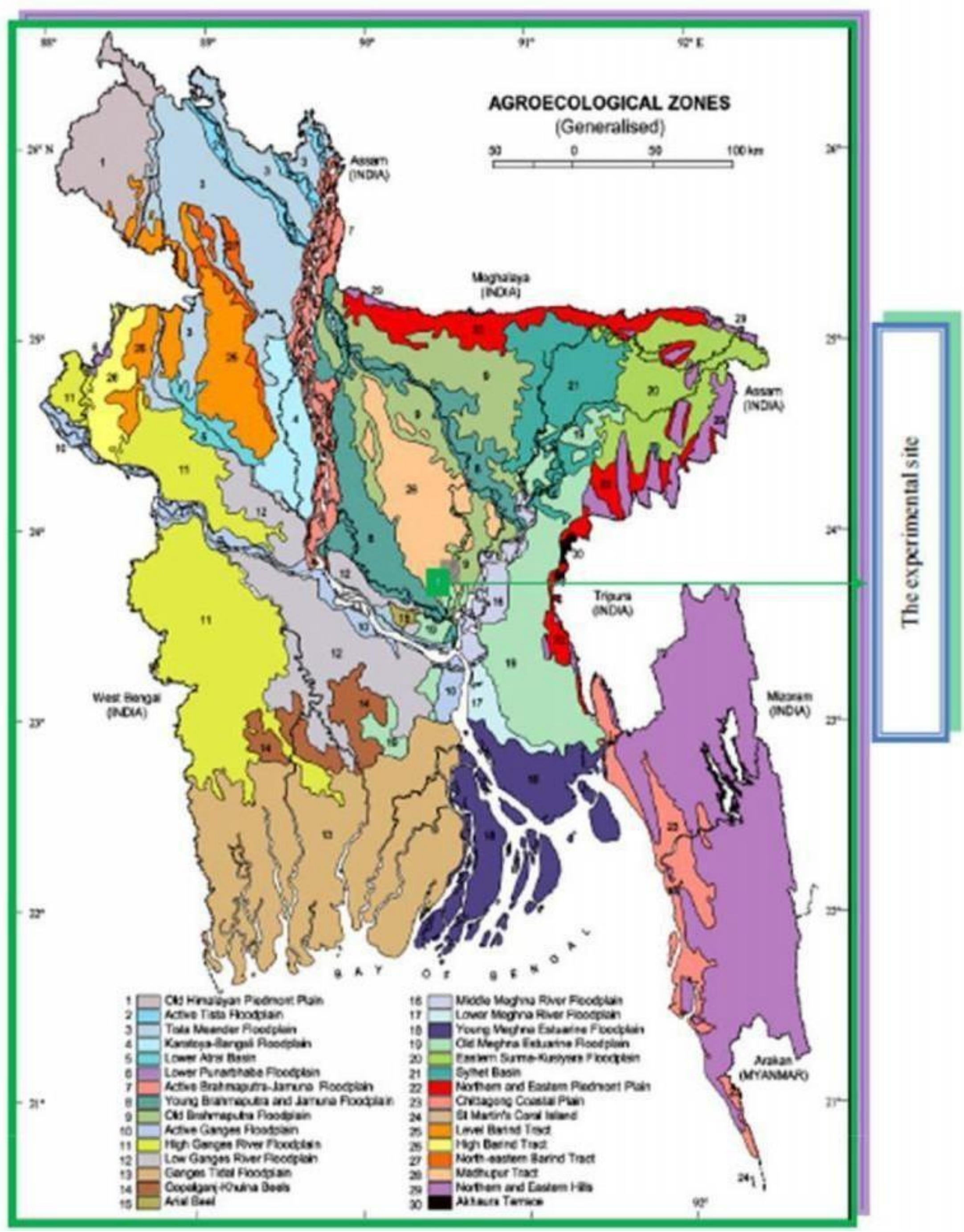

Plate 4. Experimental location on the map of agro-ecological zones of Bangladesh

Appendix II. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2019 to April 2020

Month	Air temperature (ºC)		Relative humidity (%)	Total Rainfall (mm)	Sunshine (hour)
	Maximum	Minimum			
November, 2018	24.8	16.0	76	00	6.8
December, 2018	21.6	13.4	78	04	6.7
January, 2019	23.9	12.2	64	02	6.0
February, 2019	26.7	15.9	69	30	6.7
March, 2019	27.5	19.4	81	22	6.9
April, 2019	28.8	20.8	88	26	7

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

Appendix III. Soil characteristics of experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture farm field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	26
% Silt	43
% Clay	31
Textural class	Sandy loam
pH	5.9
Catayan exchange capacity	2.64 meq 100 g/soil
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10

Appendix IV. Analysis of variance on plant height at different days after transplanting (DAT) of cauliflower

Source of variation	Degree of freedom	Mean square		
		Plant height (cm) at		
		20 DAT	40 DAT	60 DAT
Replication	2	2.4102	2.0845	8.4901
Boron (A)	3	10.0841	1.2351	42.465
Molybdenum (B)	3	8.6317	27.8404	21.966
Interaction (A×B)	9	2.7378	9.9866	3.7665
Error	22	1.4204	3.3458	3.0809

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix V. Analysis of variance on number of leaves at different days after transplanting (DAT) of cauliflower

Source of variation	Degree of freedom	Mean square		
		Number of leaves at		
		20 DAT	40 DAT	60 DAT
Replication	2	2.5055	1.4431	4.4056
Boron (A)	3	1.9423	4.5897	14.808
Molybdenum (B)	3	1.1822	1.9406	1.4033
Interaction (A×B)	9	0.4031	4.1383	1.1813
Error	22	0.4955	0.6006	0.6524

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix VI. Analysis of variance on leaf length at different days after transplanting (DAT) of cauliflower

Source of variation	Degree of Freedom	Mean square Leaf length (cm) at		
		20 DAT	40 DAT	60 DAT
Replication	2	1.8448	1.1701	11.73
Boron (A)	3	1.2035	8.797	41.443
Molybdenum (B)	3	2.072	15.229	28.018
Interaction (A×B)	9	2.7983	8.7183	3.1011
Error	22	1.0944	2.1971	3.7208

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix VII. Analysis of variance on leaf breath at different days after transplanting (DAT) of cauliflower

Source of variation	Degree of freedom	Mean square Leaf breath (cm) at		
		20 DAT	40 DAT	60 DAT
Replication	2	47.313	63.037	46.266
Boron (A)	3	0.6318	7.6024	17.394
Molybdenum (B)	3	3.8709	9.9497	11.042
Interaction (A×B)	9	0.3387	5.3385	7.3214
Error	22	0.3347	0.4365	9.407

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix VIII. Analysis of variance on stem diameter, curd diameter and fresh curd weight of cauliflower

Source of variation	Degree of freedom	Mean square		
		Stem diameter (cm)	Curd diameter (cm)	Fresh curd weight (gm)
Replication	2	0.1263	2.5109	3231.2
Boron (A)	3	0.0153	1.17	1885.1
Molybdenum (B)	3	0.0442	0.7063	5808.3
Interaction (A×B)	9	0.0403	1.1973	341.98
Error	30	0.0071	0.5321	1813.1

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix IX. Analysis of variance on dry matter percentage of curd, yield/plot and yield per hectare of cauliflower

Source of variation	Degree of freedom	Mean square		
		Dry matter percentage of curd	Yield/plot	Yield per hectare
Replication	2	1.0758	0.2068	5.609
Boron (A)	3	2.8714	0.1207	3.2724
Molybdenum (B)	3	11.158	0.3717	10.083
Interaction (A×B)	9	0.4938	0.0219	0.5936
Error	30	0.0889	0.116	3.1474

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix X. Cost of production of cauliflower per hectare: A. Input cost (Tk./ha)

Treatments	Labor cost	Seed cost	Insecticide cost (Tk./ha)	Irrigation	Cowdung	Fertilizer					Sub- Total (A)
						Urea	TSP	MP	B	Mo	
B_0M_0	76500	10000	18000	20000	15000	4800	3200	6250	0	0	153750
B_0M_1	76500	10000	18000	20000	15000	4800	3200	6250	0	300	154050
B_0M_2	76500	10000	18000	20000	15000	4800	3200	6250	0	600	154350
B_0M_3	76500	10000	18000	20000	15000	4800	3200	6250	0	900	154650
B_1M_0	76500	10000	18000	20000	15000	4800	3200	6250	200	0	153950
B_1M_1	76500	10000	18000	20000	15000	4800	3200	6250	200	300	154250
B_1M_2	76500	10000	18000	20000	15000	4800	3200	6250	200	600	154550
B_1M_3	76500	10000	18000	20000	15000	4800	3200	6250	200	900	154850
B_2M_0	76500	10000	18000	20000	15000	4800	3200	6250	400	0	154150
B_2M_1	76500	10000	18000	20000	15000	4800	3200	6250	400	300	154450
B_2M_2	76500	10000	18000	20000	15000	4800	3200	6250	400	600	154750
B_2M_3	76500	10000	18000	20000	15000	4800	3200	6250	400	900	155050
B_3M_0	76500	10000	18000	20000	15000	4800	3200	6250	600	0	154350
B_3M_1	76500	10000	18000	20000	15000	4800	3200	6250	600	300	154650
B_3M_2	76500	10000	18000	20000	15000	4800	3200	6250	600	600	154950
B_3M_3	76500	10000	18000	20000	15000	4800	3200	6250	600	900	155250

Appendix XI. Per hectare production cost of cauliflower (Cont'd)

B. Overhead cost (Tk. /ha)

Treatment combination	Cost of lease of land for 6 months (12% of value of land Tk. 900000/ year)	Miscellaneous cost (Tk. 5% of the input cost)	Interest on running capital for 6 months (Tk. 12% of cost/year)	Subtotal (Tk) (B)	Sub-Total (A)	Total cost of production (Tk./ha) [Input cost (A)+ overhead cost (B)]
B_0M_0	40000	7687.5	8058	55745	153750	209495
B_0M_1	40000	7702.5	8070	55773	154050	209823
B_0M_2	40000	7717.5	8083	55800	154350	210150
B_0M_3	40000	7732.5	8095	55828	154650	210478
B_1M_0	40000	7697.5	8066	55763	153950	209713
B_1M_1	40000	7712.5	8079	55791	154250	210041
B_1M_2	40000	7727.5	8091	55819	154550	210369
B_1M_3	40000	7742.5	8104	55846	154850	210696
B_2M_0	40000	7707.5	8074	55782	154150	209932
B_2M_1	40000	7722.5	8087	55809	154450	210259
B_2M_2	40000	7737.5	8100	55837	154750	210587
B_2M_3	40000	7752.5	8112	55865	155050	210915
B_3M_0	40000	7717.5	8083	55800	154350	210150
B_3M_1	40000	7732.5	8095	55828	154650	210478
B_3M_2	40000	7747.5	8108	55855	154950	210805
B_3M_3	40000	7762.5	8121	55883	155250	211133

Here, T_1: Planting at 5 November, T_2: Planting at 20 November, T_3: Planting at 5 December N_0: Control (no manure application), N_1: Cowdung @ 15 t/ha, N_2: Spent mushroom compost @ 7.5 t/ha, N_3: Vermicompost @ 5 t/ha.