Response of boron and molybdenum on growth and curd yield of cauliflower (*Brassica oleracea* L.)

M.F. Hossain[1,*], M.G. Azam[2], M.R. Islam[1], M.R. Uddin[3] and M.S. Islam[1]

[1] Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Ishwardi, Pabna 6620, Bangladesh
[2] Pulses Research Center, Bangladesh Agricultural Research Institute, Ishwardi, Pabna 6620, Bangladesh
[3] Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Rahmatpur, Barishal 8211, Bangladesh
* Corresponding author: farukgolap@gmail.com
Submission: 26 July 2021 Revised: 22 December 2021 Accepted: 27 December 2021

ABSTRACT

Deficiency of boron (B) and molybdenum (Mo) may create whiptail, browning, hollow stem symptoms resulting lower yield of cauliflower. To recover these problems, a balanced dose of B and Mo with blanket doses of other nutrients should be applied in the field for maximizing the curd yield of cauliflower. Thus, the study was undertaken to observe the effect of B and Mo on cauliflower and find out their suitable dose for higher yield. This experiment was done in the experimental plot of Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Ishwardi, Pabna, Bangladesh. The treatments were T_1 = 2.0 kg/ha B + 1.0 kg/ha Mo, T_2 = 3.0 kg/ha B + 1.0 kg/ha Mo, T_3 = 2.0 kg/ha B + 1.5 kg/ha Mo, T_4 = 3.0 kg/ha B + 1.5 kg/ha Mo, T_5 = 2.0 kg/ha B + 2.0 kg/ha Mo, T_6 = 3.0 kg/ha B + 2.0 kg/ha Mo and T_7 = 0 kg/ha B + 0 kg/ha Mo (control). The experiment was designed as a randomized complete block design with 3 replications and each replication was considered as a block. Results exhibited that the highest curd yield (40.00 ± 1.67 t/ha) was obtained from 3.0 kg/ha B + 1.5 kg/ha Mo (T_4) and the lowest yield (26.86 ± 1.39 t/ha) was obtained from the control. The highest gross return (US$ 5,600), gross margin (US$ 3,786), and benefit-cost ratio (3.06) were also found in T_4 treatment. So, it may be concluded that the application of 3.0 kg/ha B + 1.5 kg/ha Mo could be recommended for maximizing the curd yield of cauliflower in Bangladesh.

Keywords: Micronutrients, morphology, performance, correlation, economics, cauliflower

Thai J. Agric. Sci. (2021) Vol. 54(3): 198−211

INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis* L.) is the most popular vegetable all over the world belonging to the family Brassicaceae. In Bangladesh, the cultivated area under cauliflower is about 21.677 thousand hectares with a total production of 3.05 million tons (BBS, 2019). The average yield of cauliflower in Bangladesh is very low compared to other countries. Several factors are believed to be responsible for this poor performance. Nutrient management especially micronutrients is one of the main reasons for low yield. But micronutrients have an important role in the physiology of crops and are required for plant activities such as aspiration, meristematic developments, chlorophyll formation, photosynthesis, tannin, and phenolic compound development. To harness the highest yield performance, micronutrient supplementation is essential. Boron (B) and molybdenum (Mo) are very important micronutrients than others for growth and development of cauliflower.

B deficiency is a common deficiency of the micronutrient around the world and causes large losses in the production and crop quality of cauliflower. It affects the vegetative and reproductive growth of plants, resulting in inhibition of cell expansion, death of meristem, and reduced yield. B deficiency and exposure of curds to sunlight during development causes browning (Norman, 1992; Fritz *et al*., 2009). It also creates a hollow stem in cauliflower. Hollow areas extend from below curd when the core or fleshy center splits due to uneven growth rate with the rest of the plant (Masarirambi *et al*., 2013). Under severe B deficient conditions, cauliflower plants showing such symptoms are unlikely to form a head. Reproductive growth, especially flowering, fruit, and seed set is more sensitive to B deficiency than vegetative growth (da Silva *et al.*, 2008). Cauliflower is the most sensitive crop to Mo deficiency. The deficiency develops 'whiptail' in cauliflower. Whiptail results in a deformed growing point, causing no head to develop, as well as leaf blades consisting mostly of midribs (Sharma, 2002). Adventitious buds may form on the lower point of the stem of severely affected plants and the shoot, and the suckers may produce small curds.

B plays a key role in cell division, cell wall extension, and pollen growth, which affects seeds as well as fruit sets (Sharma *et al*., 1999). B increases the vegetative growth of cole crops (Singh, 2003). Its application in the soil increased the yield and quality of broccoli (Yang *et al.*, 2000). B enhances flower development, pollen grain formation, pollen viability, pollen tube growth, and seed development in green gram (Praveena *et al*., 2018). The application of B significantly increased curd diameter, curd weight, and curd yield of cauliflower (Kumar and Chaudhary, 2002). Mo is an essential component of nitrogen-fixing enzyme nitrogenase and nitrate reductase (BARC, 2018). The nitrate reductase is essential in the assimilation of nitrates since it catalyzes the first step of the reduction of NO_3 to NH_3. The other major molybdo-protein of plants includes nitrogenase, which fixes atmospheric nitrogen to NH_3, which is assimilated by plants (Adesoji *et al*., 2009). Plants need Mo for chemical changes related to nitrogen nutrition. In non-legumes (such as broccoli, tomatoes, lettuce, sunflower, and corn), Mo allows plants to use up nitrate absorbed from the soil. Noor *et al*. (1996) studied the response of cauliflower to zinc (Zn) and Mo and recorded the highest curd yield of cauliflower. Hossain *et al.* (2018) observed that the application of Mo increased the seed yield of cauliflower. Mo application significantly increased the canopy, nodule formation, and yield of the crop (Khan *et al.,* 2019). Ranjan *et al.* (2020) found higher yield and good vegetative growth of the crop by foliar application of B and Mo. Yield and quality parameters were also influenced significantly due to B and Mo application (Ningawale *et al.*, 2016). Moreover, the farmers are very much reluctant to use B and Mo in cauliflower cultivation and necessary information regarding the optimum dose of B and Mo for curd yield of cauliflower under Bangladesh condition are scanty. In this context, the present investigation was undertaken to observe the effects of B and Mo on growth and curd yield of cauliflower and to find out the optimum dose of these micronutrients for maximizing the yield of cauliflower under Bangladesh agro-climatic conditions.

MATERIALS AND METHODS

Experimental Site

The research experiment was carried out at Regional Agricultural Research Station (RARS), Bangladesh Agricultural Research Institute (BARI), Ishwardi, Pabna, Bangladesh. The experimental site was at 24.03° N latitude and 89.05°E longitude with an elevation of 16 m above sea level. The site falls into the agro-ecological zone 11 (High Ganges River Floodplain). The experimental period was October to December 2015. Cauliflower is a cole crop and October to February is the winter Rabi season (winter) in Bangladesh.

Climatic Condition of the Research Area

The experimental area belongs to a subtropical climatic zone which is characterized by heavy rainfall (1,500–1,600 mm), high humidity (80–87%), high temperature (32–36ºC), and relatively long day period (>13 hours) during Kharif season (April to September) and scarce rainfall, low humidity (60–70%), low temperature (14–27ºC), and short day period (<11 hours) during Rabi season (October to March). Weather data on weekly average temperature, humidity, and rainfall during the experimental period were recorded regularly at the meteorological station of RARS, BARI, Ishwardi, Pabna. Data are presented in Figure 1.

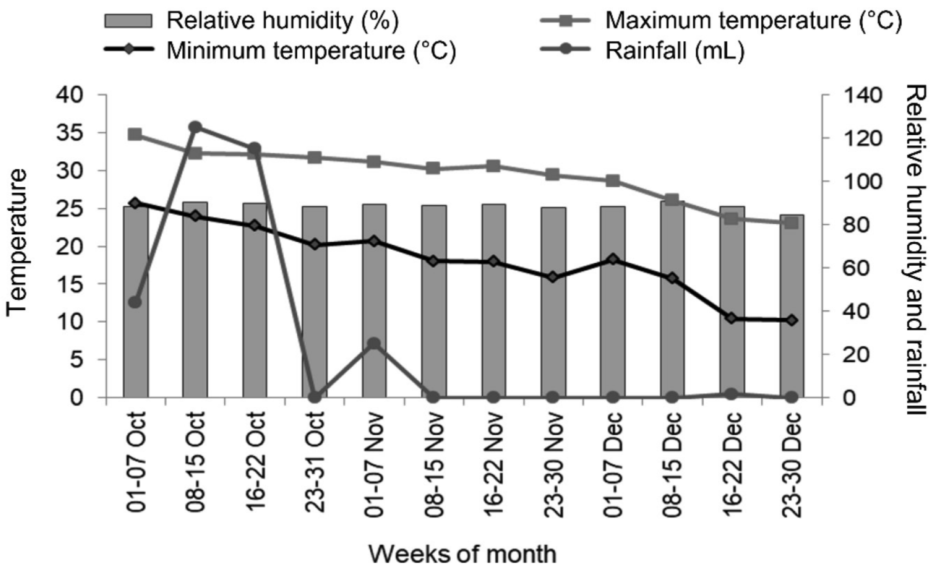

Figure 1 Weekly average temperature, relative humidity, and total rainfall prevailed during 2015

Soil Properties of the Experimental Plots

The initial soil test for chemical properties was done at Soil Science Laboratory, Soil Science Division, BARI, Gazipur. The soil of the experimental site was medium-high and clay loam in texture. According to Food and Agriculture Organization of the United Nations (FAO, 1988), it is calcareous type soil having 7.48 pH, 1.11% organic matter, 0.06% total nitrogen (N), 12 mg/kg available phosphorus (P), 0.11 cmol/kg exchangeable potassium (K), 12 mg/kg sulphur (S), 0.18 mg/kg boron (B), 1.90 mg/kg zinc (Zn), and 0.07 mg/kg molybdenum (Mo). The status of total N (%), B, and Mo of the soil was below the critical level. So, these nutrients should be added to the soil for crop growth and higher yield. The nutrient status is presented in Table 1.

Plant Material

BARI Fulcopi-1 was used as plant material. It is a variety of cauliflower released by the Olericulture Division, Horticulture Research Centre, BARI, Gazipur, Bangladesh.

Design and Treatments of the Experiment

The experiment was laid out in the randomized complete block design (RCBD) with triplicates. Each replication was considered as a block. Each block was divided into nine unit plots each measuring 10 m × 1 m with 30 cm drain between two beds. The block to block and plot to plot distances were 1 m and 30 cm, respectively. The treatments were randomly distributed to each plot. Twenty plants were accommodated in a plot with a plant spacing of 50 cm apart and row to row distance of 60 cm. The treatments were T_1 = 2.0 kg/ha B + 1.0 kg/ha Mo, T_2 = 3.0 kg/ha B + 1.0 kg/ha Mo, T_3 = 2.0 kg/ha B + 1.5 kg/ha Mo, T_4 = 3.0 kg/ha B + 1.5 kg/ha Mo, T_5 = 2.0 kg/ha B + 2.0 kg/ha Mo, T_6 = 3.0 kg/ha B + 2.0 kg/ha Mo and T_7 = 0 kg/ha B + 0 kg/ha Mo (control).

Table 1 Physical and chemical properties of initial experimental soil

Soil properties	Value	Critical level	Method	Reference
Physical properties				
Sand (%)	29.00	-		
Silt (%)	32.00	-		
Clay (%)	49.00	-		
Textural class	Clay loam		Hydrometer method	Day (1965)
Chemical properties				
Organic matter	1.11	-	Wet oxidation method	Broadbent (1965)
pH	7.48	-	Glass-electrode pH meter with 1:1.25 soil-water ratios	McLean (1982)
Total nitrogen (g/kg)	0.06	0.12	Micro-Kjeldahl method	Bremner (1996)
Available phosphorus (mg/kg)	12.00	10.00	Molybdate blue ascorbic acid	Bray and Kurtz (1945)
Exchangeable potassium (cmol/kg)	0.11	0.12	Flame photometer	Toth and Prince (1949)
Available sulphur (mg/kg)	12.00	10.00	Turbidity method using $BaCl_2$	Fox *et al.* (1964)
Available boron (mg/kg)	0.18	0.20	Calcium chloride extraction method	Bingham (1982)
Available zinc (mg/kg)	1.90	0.60	Atomic absorption spectrophotometer	Lindsay and Norvell (1978)
Available molybdenum (mg/kg)	0.07	0.10	Sodium hydroxide (NaOH)-extraction method	Grigg (1953), Haley and Melsted (1957)

Experimental Procedures

Seedling raising

Seed of BARI Fulcopi-1 was sown in the well-prepared nursery beds on 1 October 2015. Light irrigation by watering cane was done to mist the soil of the beds. After germination, when the seedlings attained the height of 3 cm then the seedlings were transplanted in the other nursery beds 10 cm apart for proper growth and development of the seedlings. Weeding and mulching were done when needed for good aeration.

Land preparation

The land of the experimental plot was first opened on 15 October 2016 with a power tiller. After 7 days, the land was deep ploughed and cross-ploughed followed by laddering to obtain a good tilt for proper growth and development for the plant. All weeds and debris were removed from the field.

Seedling transplanting

Thirty days old healthy seedlings were transplanted in the experimental plot maintaining

60 × 50 cm spacing in the evening. Before transplantation, the nursery beds were irrigated so that the seedlings could be easily taken out from the beds without damage to the root. After one week of transplantation, deceased seedlings were replaced by fresh seedlings to attain a uniform stand.

Application of manure and common fertilizer

The land was fertilized with well-decomposed cow dung at the rate of 15 t/ha and N, P, K, and S, at the rate of 120, 55, 100, and 15 kg/ha, respectively. The source of N, P, K, S, Zn, B, and Mo was urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum, zinc sulphate, boric acid, and sodium molybdate, respectively. The entire amount of cow dung, TSP, gypsum, zinc sulphate, boric acid, and sodium molybdate were incorporated in the plot during the last stage of land preparation. After planting, urea and MOP were applied in 3 installments at 15, 30, and 45 days after planting (DAP).

Intercultural operations

After transplantation, the experimental plot was irrigated by watering cane and the second irrigation (flood irrigation) was done 3 days after transplantation. After this, irrigations were done after fertilizer application at 15, 30, and 45 DAP. Three weedings were also done just before fertilization for weed control. In the early stage of transplantation, damping off disease was occurred, and it was controlled by spraying Autostin 50WDG at 2 g per liter of water. Cercospora leaf spot disease was found during curd initiation, and it was controlled by spraying Rovral 50 WP at 2 g per liter of water at 10 days interval for 3 times.

Data Collection

Data on different characters were collected and the procedure of data collection is given as below.

Plant height

Plant height (cm) was taken at the time of curd harvest. Randomly 10 plants were selected for measuring the plant height and average plant height was calculated.

Number of leaves per plant

The number of leaves produced by the plant was counted from randomly selected 10 plants at the curd initiation stage and an average number of leaves per plant was calculated. The smallest young leaf at the growing point of the plant was excluded from the count.

Days to curd initiation and curd harvest

The total number of days required for visible curd initiation from the date of transplanting was counted from randomly selected 10 plants and an average of the same was calculated. Similarly, days to curd harvest was calculated.

Curd length and curd diameter

The length (cm) of the curd was measured from randomly selected 10 plants at harvest by a scale from base to top of the curd. Then average curd length was calculated. Curd diameter (cm) was measured at the broadest part of the curd and the average was calculated.

Marketable curd weight

Marketable curd weight (g) was taken at the time when the curd was ready for market.

Curd yield

The curd yield (t/ha) of cauliflower was calculated from the plot yield and it was converted to ton per hectare

Statistical Analysis

Mean values were subjected to analysis of variance to test the significance for each character by using the computer statistical 'R' platform (R Core Team, 2016) following the basic procedure outlined by Gomez and Gomez (1984). The means separations were done by least significant difference (LSD) at 0.05 levels of probability with agricolae package.

Cost and Return Analysis

The cost of production was analyzed to find out the most profitable treatments. Non-material cost, material input cost, and overhead cost ware recorded for all treatments and calculated per hectare basis. The price of cauliflower was taken at the wholesale market for economic analysis. The benefit-cost ratio (BCR) was calculated by the following formula.

$$\text{Benefit-cost ratio} = \frac{\text{Gross return}}{\text{Total variable cost}}$$

RESULTS AND DISCUSSION

Plant Height

Plant height at harvest was significantly affected by different treatments ($P < 0.05$). The highest plant height (52.64 ± 4.86 cm) was measured from T_6 treatments (3.0 kg/ha B + 2.0 kg/ha Mo), and the lowest plant height (43.39 ± 3.83 cm) was measured from control (Figure 2A). Plant height of cauliflower was significantly influenced by increasing doses of B (Pandey *et al*., 2020). B is essential for structural integrity to the cell wall in the plants. It helps for sugar or energy translocation into growing parts of the plant, thus it affects carbon and nitrogen metabolism and increases plant height. B is taken into consideration as important for actively growing plant parts especially for root tips, new leaf, and bud development. Adequate B improves phosphorus and potassium uptake maintaining proper function and structure of cell membrane. Thakur *et al*. (1991) stated that B application enhances the plant height of cauliflower. The results of the experiment are in accordance with their findings. Mo helps plants with nitrogen assimilation and potassium absorption. The use of adequate Mo improves plant health and growth. In cauliflower, Mo deficiency appears symptoms in younger leaf tissues with the characteristic loss of proper lamina development, leathery leaves, and meristem necrosis and plants become stunted. Singh *et al.* (2017b) observed that the use of B and Mo application enhances plant height of cauliflower.

Number of Leaves per Plant

The application of boron and molybdenum showed highly significant variation in the number of leaves per plant. An increasing trend was observed in all treatments compared to control regarding the number of leaves per plant. The maximum number of leaves per plant (19.03 ± 2.00) was counted from T_4 treatment (3.0 kg/ha B + 1.5 kg/ha Mo) which was statistically similar to T_6 treatment (3.0 kg/ha B + 2.0 kg/ha Mo). The minimum number of leaves per plant (15.07 ± 1.00) was counted from the control (Figure 2B). Ghosh and Hasan (1997) reported a similar result. Noor *et al.* (2002) got a maximum number of leaves per plant for cauliflower. Thakur *et al*. (1991) stated that B application increased the number of leaves per plant of cauliflower. Sharma (2002) reported that the probable reasons for enhanced plant height and the number of leaves of cauliflower may be due to the effects of Mo on vegetative growth which ultimately lead to more photosynthetic activities. Similar results were also reported by Rahman *et al*. (1992). Singh *et al*. (2017a) found that micronutrients (B and Mo) significantly increased the plant height and number of leaves per plant.

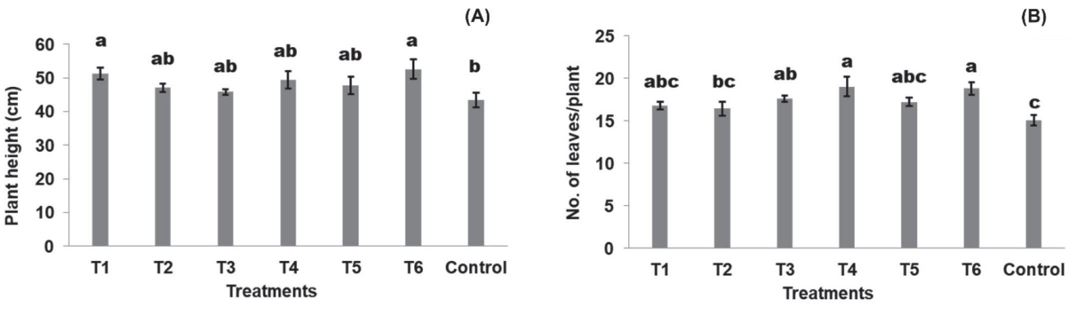

Figure 2 Effect of boron (B) and molybdenum (Mo) on (A) plant height and (B) number of leaves per plant of cauliflower. T_1 = 2.0 kg/ha B + 1.0 kg/ha Mo, T_2 = 3.0 kg/ha B + 1.0 kg/ha Mo, T_3 = 2.0 kg/ha B + 1.5 kg/ha Mo, T_4 = 3.0 kg/ha B + 1.5 kg/ha Mo, T_5 = 2.0 kg/ha B + 2.0 kg/ha Mo, T_6 = 3.0 kg/ha B + 2.0 kg/ha Mo, T_7 = 0 kg/ha B + 0 kg/ha Mo (control). Different letters on each bar indicate significant difference according to least significant difference at $P < 0.05$.

Days to Curd Initiation and Harvest

Early curd initiation was enhanced by different treatments. The earliest curd initiation (65.56 ± 2.50 days) occurred in T_4 treatment (3.0 kg/ha B + 1.5 kg/ha Mo) whereas, curd initiation was delayed (70.00 ± 1.00 days) in control where no B and Mo was used (Figure 3A). B affects chlorophyll content. Since B is a constituent of chloroplast it acted positively for the synthesis of chlorophyll, cellular differentiation, and development. Almost similar trend was observed in the case of curd harvest. The earliest curd harvest (73.00 ± 1.00 days) was observed in T_5 treatment which was statistically similar to T_4 treatment (Figure 3B) whereas delayed curd harvest was found in T_1 treatment (76.78 ± 0.53 days) and control (76.56 ± 0.51 days). It was observed that the curd initiation period required in plants decreased with the increasing levels of micronutrients application. This might be due to the positive role played by regulating micronutrients in the balanced absorption of nutrients might improve physiological activities, which resulted in the endogenous growth hormone synthesis responsible for early curd formation in plants. The present result is in agreement with the findings of Kumar and Chaudhary (2002).

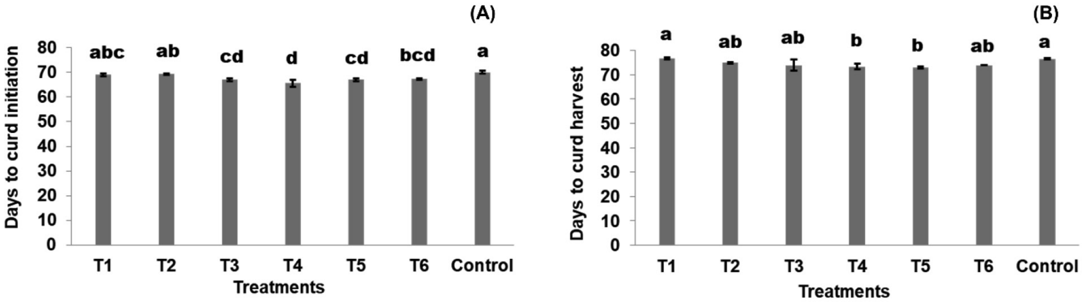

Figure 3 Effect of boron (B) and molybdenum (Mo) on (A) days to curd initiation and (B) days to curd harvest of cauliflower. T_1 = 2.0 kg/ha B + 1.0 kg/ha Mo, T_2 = 3.0 kg/ha B + 1.0 kg/ha Mo, T_3 = 2.0 kg/ha B + 1.5 kg/ha Mo, T_4 = 3.0 kg/ha B + 1.5 kg/ha Mo, T_5 = 2.0 kg/ha B + 2.0 kg/ha Mo, T_6 = 3.0 kg/ha B + 2.0 kg/ha Mo, T_7 = 0 kg/ha B + 0 kg/ha Mo (control). Different letters on each bar indicate significant difference according to least significant difference at $P < 0.05$.

Curd Length and Curd Diameter

The curd length and curd diameter showed significant differences due to B and Mo application and all the treatment combinations produced longer curd compared to control. However, curd length was maximum (12.03 ± 0.50 cm) in T_6 treatment which was statistically similar to T_4 treatment (11.99 ± 0.01 cm), and curd length was minimum (9.86 ± 0.24 cm) in control (Figure 4A). On the other hand, the maximum curd diameter (17.84 ± 1.19 cm) was found in T_4 treatment, and the minimum curd diameter (14.17 ± 0.50 cm) was found in control (Figure 4B). Application of B and Mo increased the curd diameter of cauliflower (Kumar and Chaudhary, 2002). The formation of bigger curd with the application of higher levels of micronutrients might be done to a higher synthesis of carbohydrates and their translocation to the curd, which subsequently formed higher curd of cauliflower. Prasad and Yadav (2003) found similar results for cauliflower.

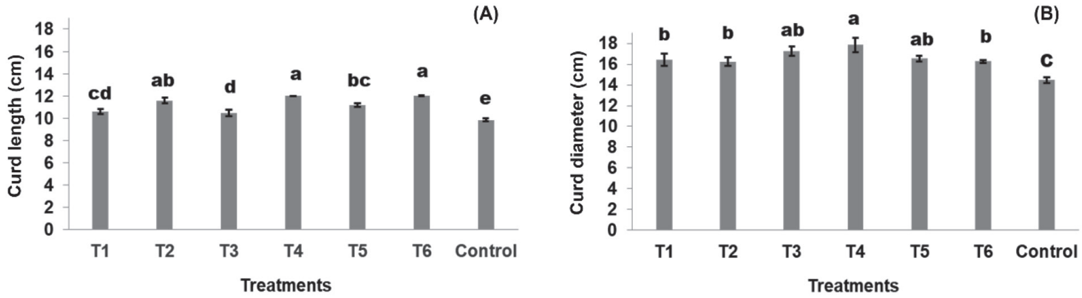

Figure 4 Effect of boron (B) and molybdenum (Mo) on (A) curd length and (B) curd diameter of cauliflower. T_1 = 2.0 kg/ha B + 1.0 kg/ha Mo, T_2 = 3.0 kg/ha B + 1.0 kg/ha Mo, T_3 = 2.0 kg/ha B + 1.5 kg/ha Mo, T_4 = 3.0 kg/ha B + 1.5 kg/ha Mo, T_5 = 2.0 kg/ha B + 2.0 kg/ha Mo, T_6 = 3.0 kg/ha B + 2.0 kg/ha Mo, T_7 = 0 kg/ha B + 0 kg/ha Mo (control). Different letters on each bar indicate significant difference according to least significant difference at $P < 0.05$.

Marketable Curd Weight

B and Mo influenced the marketable curd weight ($P < 0.05$). The highest individual marketable curd weight (1,200 ± 50 g) was obtained from T_4 treatment followed by T_6 and T_3 treatments and the lowest marketable curd weight (806 ± 42 g) was obtained from control (Figure 5A). Curd weight increased probably due to the application of optimum B and Mo under deficient conditions. It enhanced uptake of major nutrients which resulted in higher photosynthesis in plants and increased curd size, yield, and quality of cauliflower. Sharma (2002) reported that the use of B and Mo significantly increased the curd size and seed yield of cauliflower. Singh (2003) observed that foliar application of B and Mo increased the curd weight of cauliflower.

Curd yield

Curd yield varied significantly with the application of B and Mo fertilizers ($P < 0.05$). The maximum curd yield (40.00 ± 1.67 t/ha) was measured in the T_4 treatment (Figure 5B). This increase might be due to the effect of B and Mo. B enhances the translocation of carbohydrates from leaves to reproductive tissues in the curd whereas Mo stimulates the photosynthesis and increases the metabolic process. Kotur and Kumar (1989) found almost similar results. The lowest curd yield (26.86 ± 1.39 t/ha) was obtained from the control. Sharma and Ramchandra (1991) stated that B deficiency significantly reduced leaf water potential, stomatal opening, transpiration rate, net photosynthesis, and intercellular CO_2 concentration which ultimately decreased yield. Khadka *et al.* (2005) reported the better cauliflower curd produced from the application of B. Foliar application of B, Mo, and other micronutrients significantly increased the yield and quality of cauliflower (Chaudhari *et al*., 2017). These results are in accordance with Sharma (2002), Kumar and Chaudhary (2002), Chattopadhyay and Mukhopadyay (2003), Kumar (2005), and Mahmud *et al*. (2005).

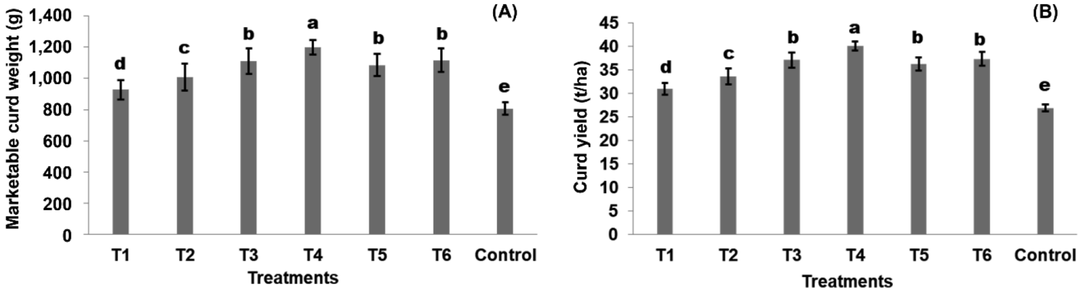

Figure 5 Effect of boron (B) and molybdenum (Mo) on (A) marketable curd weight and (B) curd yield of cauliflower. T_1 = 2.0 kg/ha B + 1.0 kg/ha Mo, T_2 = 3.0 kg/ha B + 1.0 kg/ha Mo, T_3 = 2.0 kg/ha B + 1.5 kg/ha Mo, T_4 = 3.0 kg/ha B + 1.5 kg/ha Mo, T_5 = 2.0 kg/ha B + 2.0 kg/ha Mo, T_6 = 3.0 kg/ha B + 2.0 kg/ha Mo, T_7 = 0 kg/ha B + 0 kg/ha Mo (control). Different letters on each bar indicate significant difference according to least significant difference at P < 0.05.

Economic Performance

Farmers accept new technology when it is economically viable, and it depends on the benefit-cost ratio. The results illustrated that all treatment combinations showed a higher benefit-cost ratio than control. The highest gross return (US$ 5,600 ± 233) and gross margin (US$ 3,786 ± 233) were obtained from T_4 treatment. The maximum benefit-cost ratio (3.06 ± 0.13) was also obtained from the same treatment (Table 2). Hence, T_4 treatment would be economically profitable for cauliflower production.

Table 2 Benefit-cost analysis of cauliflower under different treatment combinations

Treatments	Curd yield (t/ha)	Gross return (US$/ha)	Total variable cost (US$/ha)	Gross margin (US$/ha)	Benefit-cost ratio
T_1	30.92 ± 2.10^{d}	4,329 ± 295^{d}	1,714^{f}	2,615 ± 295^{e}	2.52 ± 0.17^{d}
T_2	33.61 ± 2.93^{c}	4,706 ± 409^{c}	1,720^{e}	2,986 ± 409^{d}	2.73 ± 0.24^{c}
T_3	37.03 ± 2.80^{b}	5,185 ± 392^{b}	1,808^{d}	3,377 ± 392^{b}	2.87 ± 0.22^{b}
T_4	40.00 ± 1.67^{a}	5,600 ± 233^{a}	1,814^{c}	3,786 ± 233^{a}	3.06 ± 0.13^{a}
T_5	36.20 ± 2.40^{b}	5,068 ± 336^{b}	1,902^{b}	3,166 ± 336^{c}	2.66 ± 0.18^{c}
T_6	37.22 ± 2.54^{b}	5,211 ± 356^{b}	1,908^{a}	3,303 ± 336^{bc}	2.73 ± 0.19^{c}
T_7	26.86 ± 1.38^{e}	3,760 ± 195^{e}	1,514^{g}	2,246 ± 195^{f}	2.48 ± 0.13^{d}
LSD	1.22	171.03	8.02	171.03	0.09
CV (%)	1.99	1.97	2.55	3.13	1.83
P-value	0.001	0.001	0.001	0.001	0.001

Note: T_1 = 2.0 kg/ha B + 1.0 kg/ha Mo, T_2 = 3.0 kg/ha B + 1.0 kg/ha Mo, T_3 = 2.0 kg/ha B + 1.5 kg/ha Mo, T_4 = 3.0 kg/ha B + 1.5 kg/ha Mo, T_5 = 2.0 kg/ha B + 2.0 kg/ha Mo, T_6 = 3.0 kg/ha B + 2.0 kg/ha Mo and T_7 = 0 kg/ha B + 0 kg/ha Mo (control). Rate: US$ 1 = BD Tk 85, market price of cauliflower = 0.14 US$/kg. LSD = least significant difference, CV = coefficient of variance. Different letters in a column indicate significant difference according to least significant difference at P < 0.05

Correlation Coefficient

The Pearson's correlation coefficient of phenotypic characters of cauliflower was investigated (Table 3). The results found that yield per hectare (YPH) demonstrated a highly significant and positive correlation with number of leaves per plant (0.92; P < 0.01), curd length (0.77; P < 0.01), curd diameter (0.89; P < 0.01), and marketable curd weight (1.00; P < 0.01). Yield per hectare also showed a significantly negative correlation with days to curd initiation (-0.64; P < 0.01) and days to curd harvest (-0.90; P < 0.01). These results indicated that more number of leaves per plant enhanced more photosynthesis, accumulated food in curd, and increased curd length, curd diameter, and marketable curd weight resulted in yield maximization. These findings agree with those of Jamwal *et al*. (1992), Dutta and Korla (1991), Kumar and Korla (2001), Sharma *et al*. (2006), and Kanwar and Korla (2002) in cauliflower.

Table 3 Phenotypic correlation coefficients of growth and curd yield of cauliflower among the treatments

	NLP	DCI	DCH	CL	CD	MCW	YPH
PH	0.70*	-0.39	-0.18	0.67*	0.44	0.46	0.46
NLP		-0.90**	-0.72*	0.79*	0.81*	0.92**	0.92**
DCI			0.87*	-0.61	-0.85*	-0.94**	-0.64**
DCH				-0.64	-0.67	-0.89**	-0.90**
CL					0.57	0.77**	0.77**
CD						0.89**	0.89**
MCW							1.00**

Note: PH = plant height, NLP = number of leaves per plant, DCI = days to curd initiation, DCH = days to curd harvest, CL = curd length, CD = curd diameter, MCW = marketable curd weight, YPH = yield per hectare. ** Significant at P < 0.01, * significant at P < 0.05

Marketable curd weight also showed a high negative relationship with days to curd initiation (-0.94; P < 0.01) and days to curd harvest (-0.89; P < 0.01). The correlation coefficients indicated that number of leaves per plant had a significant positive association with plant height (0.70; P < 0.05), curd length (0.79; P < 0.05), curd diameter (0.81; P < 0.05) and marketable curd weight (0.92; P < 0.01) but had a negative relationship with days to curd initiation (-0.90; P < 0.01) and days to curd harvest (-0.72; P < 0.05). On the other hand, days to curd initiation had high positive correlation with days to curd harvest (0.87; P < 0.05) but had high negative association with curd diameter (-0.85; P < 0.05) and marketable curd weight (-0.94; P < 0.01).

CONCLUSIONS

The findings of the study exhibited that the application of B and Mo responded well to the curd yield of cauliflower. Applying 3.0 kg/ha B + 1.5 kg/ha Mo yielded a higher curd yield of cauliflower. This level of B and Mo also gave a higher economic return. A positive correlation was found between curd yield and almost all the study traits. Thus, the level of 3.0 kg/ha B + 1.5 kg/ha Mo may be recommended for maximizing the curd yield of cauliflower in Northern Bangladesh.

REFERENCES

Adesoji, A.G., I.U. Abubakar and D.B. Ishaya. 2009. Performance of soybean (*Glycine max* (L.) Merrill) as influenced by method and rate of molybdenum application in Samaru, Northern Guinea Savanna of Nigeria. Am. Eurasian J. Sustain. Agric. 3(4): 845–849.

BARC (Bangladesh Agricultural Research Council). 2018. Fertilizer Recommendation Guide. Bangladesh Agricultural Research Council, Dhaka, Bangladesh.

BBS (Bangladesh Bureau of Statistics). 2019. Year Book of Agricultural Statistics of Bangladesh. Ministry of Planning, Dhaka, Bangladesh.

Bingham, F.T. 1982. Boron, pp. 431–448. *In*: A.L. Page, R.H. Miller and D.R. Keeney, (Eds), Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. 2nd Edition. Agronomy No. 9. American Society of Agronomy, Inc., Soil Science Society of America, Inc., Madison, Wisconsin, USA.

Bray, R.H. and L.T. Kurtz. 1945. Determination of total, organic, and available forms of phosphorus in soils. Soil Sci. 59(1): 39–46.

Bremner, J.M. 1996. Nitrogen-total, pp. 1085–1121. *In*: D.L. Sparks, A.L. Page, P.A. Helmke, R.H. Loeppert, P.N. Soltanpour, M.A. Tabatabai, C.T. Johnston and M.E. Sumner, (Eds), Methods of Soil Analysis. Part 3. Chemical Methods. Soil Science Society of America Book Series No. 5. Soil Science Society of America, Inc., American Society of Agronomy, Inc., Madison, Wisconsin, USA.

Broadbent, F.E. 1965. Organic matter, pp. 1397–1400. *In*: C.A. Black, D.D. Evans, J.L. White, L.E. Ensminger, F.E. Clark and R.C. Dinauer, (Eds), Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. Agronomy No. 9. American Society of Agronomy, Inc., Madison, Wisconsin, USA.

Chattopadhyay, S.B. and T.P. Mukhopadhyay. 2003. Effect of foliar application of boron and molybdenum on growth and yield of cauliflower in Terai zone of West Bengal. Environ. Ecol. 21(4): 955–959.

Chaudhari, V.J., N.K. Patel, B.M. Tandel and C. Vibhuti. 2017. Effect of foliar spray of micronutrients on growth and yield of cauliflower (*Brassica oleracea* L. var. *botrytis*). Int. J. Chem. Stud. 5(6): 1133–1135.

da Silva, D.H., M.L. Rossi, A.E. Boaretto, N. de Lima Nogueira and T. Muraoka. 2008. Boron affects the growth and ultrastructure of castor bean plants. Sci. Agric. (Piracicaba, Braz.). 65(6): 659–664.

Day, P.R. 1965. Particle fractionation and particle-size analysis, pp. 545–567. *In*: C.A. Black, D.D. Evans, J.L. White, L.E. Ensminger, F.E. Clark and R.C. Dinauer, (Eds), Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. Agronomy No. 9. American Society of Agronomy, Inc., Madison, Wisconsin, USA.

Dutta, S.K. and B.N. Korla. 1991. Variability studies in cauliflower (late group). II. Correlation and regression studies. Hort. J. 4(2): 33–38.

FAO (Food and Agriculture Organization of the United Nations). 1988. FAOSTAT. Available Source: www.fao.org/faostat/en/#data/QC.

Fox, R.L., R.A. Olson and H.F. Rhoades. 1964. Evaluating the sulfur status of soils by plant and soil tests. Soil Sci. Soc. Am. J. 28(2): 243–246.

Fritz, V.A., C.J. Rosen, M.A. Grabowski, W.D. Hutchison, R.L. Becker, C.B.S. Tong, J.A. Wright and T.T. Nennich. 2009. Growing broccoli, cabbage and cauliflower in Minnesota. University of Minnesota Extension Bulletin, Minnesota, USA.

Ghosh, S.K. and M.A. Hasan. 1997. Effect of boron on growth and yield of cauliflower. Ann. Agric. Res. 18(3): 391–392.

Gomez, K.A. and A.A. Gomez. 1984. Statistical Procedures for Agricultural Research. 2nd Edition. A Wiley-Interscience Publication, John Wiley & Sons, Inc., New York, USA.

Grigg, J.L. 1953. A rapid method for the determination of molybdenum in soils. Analyst. 78: 470–473.

Haley, L.E. and S.W. Melsted. 1957. Preliminary studies of molybdenum in Illinois soils. Soil Sci. Soc. Am. J. 21(3): 316–319.

Hossain, M.F., M.R. Uddin, M.R. Humauan and J. Hossain. 2018. Effect of molybdenum and its application on seed production of cauliflower. Bull. Inst. Trop. Agr., Kyushu Univ. 41: 67–72.

Jamwal, R.S., S. Prakash and C.L. Bharwdwaj. 1992. Evaluation of economic characters for breeding programme in late group of cauliflower (*Brassica oleracea* var. *botrytis*). Indian J. Agric. Sci. 62: 369–372.

Kanwar, M.S. and B.N. Korla. 2002. Performance of biparental progenies in late cauliflower: variability and association analysis. Veg. Sci. 29(1): 13–16.

Khadka, Y.G., S.K. Rai and S. Raut. 2005. Effect of boron on cauliflower production. Nepal J. Sci. Technol. 6: 103–108.

Khan, Q.A., S.A. Cheema, M. Farooq, A. Wakeel and F.U. Haider. 2019. Monitoring the role of molybdenum and seed priming on productivity of mung bean (*Vigna radiata* L.). J. Res. Ecol. 7(1): 2417–2427.

Kotur, S.C. and S. Kumar. 1989. Response of cauliflower (*Brassica oleracea* var. *botrytis*) to boron in Chotanagpur region. Indian J. Agric. Sci. 59(10): 640–644.

Kumar, R. 2005. Cauliflower yield influenced by nitrogen and boron application. J. App. Biol. 15(1): 56–58.

Kumar, S. and B.N. Korla. 2001. Genetic variability, heritability and genetic advance for yield and its contributing traits in late cauliflower (*Brassica oleracea* var. *botrytis* L.). Himachal J. Agric. Res. 27(1–2): 114–116.

Kumar, S. and D.R. Chaudhary. 2002. Effect of FYM, molybdenum and boron application on yield attributes and yields of cauliflower. Crop Res. 24(3): 494–496.

Lindsay, W.L. and W.A. Norvell. 1978. Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Sci. Soc. Am. J. 42(3): 421–428.

Mahmud, Z.U., M.M. Rahman, M.A. Salam, S.R. Saha and M.S. Alam. 2005. Effect of sulphur, boron and molybdenum on curd yield of cauliflower. Journal of Sub Tropical Agriculture Research and Development. 3(1): 82–86.

Masarirambi, M.T., M.E. Mndzebele, P.K. Wahome and T.O. Oseni. 2013. Effects of white plastic and sawdust mulch on ‘savoy’ baby cabbage (*Brassica oleracea* var. *bullata*) growth, yield and soil moisture conservation in summer in Swaziland. Am. Eurasian J. Agric. Environ. Sci. 13(2): 261–268.

McLean, E.O. 1982. Soil pH and lime requirement, pp. 199–224. *In*: A.L. Page, R.H. Miller and D.R. Keeney, (Eds), Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. 2nd Edition. Agronomy No. 9. American Society of Agronomy, Inc., Soil Science Society of America, Inc., Madison, Wisconsin, USA.

Ningawale, D.K., R. Singh, U.S. Bose, P.S. Gurjar, A. Sharma and U.S. Gautam. 2016. Effect of boron and molybdenum on growth, yield and quality of cauliflower (*Brassica oleracea* var. *botrytis*) cv. Snowball 16. Indian J. Agric. Sci. 86(6): 825–829.

Noor, S., A.T.M. Farid, N.C. Shill and A.K.M. Hossain. 2002. Integrated nutrient management for cauliflower. Bangladesh J. Environ. Sci. 8: 25–30.

Noor, S., M. Rahman, N.C. Shill, S.K. Nandy and M.N. Anwar. 1996. Effect of zinc and molybdenum on the yield and yield components of cauliflower. Bangladesh Hort. 14 (1–2): 123–127.

Norman, J.C. 1992. Tropical Vegetable Crops. Arthur H. Stockwell Ltd., Elm Court, UK.

Pandey, S., S. Parajuli, B. Oli and S. Dhungana. 2020. Effect of different doses of boron on growth and yield of off-season cauliflower (*Brassica oleracea* var. *botrytis*) in Arghakhanchi, Nepal. Reviews in Food and Agriculture. 1(1): 12–17.

Prasad, V.M. and D. Yadav. 2003. Effect of foliar application of boron and molybdenum on the growth and yield of cauliflower (*Brassica oleracea* var. *botrytis)* cv. Snowball-16. New Agriculturist. 14(1–2): 121–128.

Praveena, R., G. Ghosh and V. Singh. 2018. Effect of foliar spray of boron and different zinc levels on the growth and yield of kharif green gram (*Vigna radiata*). Int. J. Curr. Microbiol. App. Sci. 7(8): 1422–1428.

Rahman, A., K.M. Matiar, S.M. Monowar Hossain and H.M. Monjur. 1992. Effect of sulphur, boron and molybdenum on the growth, curd weight and seed yield of cauliflower. Punjab Vegetable Grower. 27: 11–14.

Ranjan, S., S. Misra, S. Sengupta, S. Parween and U. Kumari. 2020. Influence of micronutrients on growth and yield of cauliflower. J. Pharmacogn. Phytochem. 9(1): 238–240

R Core Team. 2016. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Sharma, A., S. Sharma, S. Pathak and S. Sood. 2006. Genetic variability for curd yield and its component traits in cauliflower (*Brassica oleracea* var. *botrytis*) under high hills dry temperate conditions. Veg. Sci. 33(1): 82–84.

Sharma, P.N and T. Ramchandra. 1991. Effects of boron deficiency and recovery on water relations and photosynthesis in cauliflower. Indian J. Exp. Biol. 29(10): 967–970.

Sharma, S.K. 2002. Effect of boron and molybdenum on seed production of cauliflower. Indian J. Hort. 59(2): 177–180.

Sharma, S.K., H. Singh and U.K. Kohli. 1999. Influence of boron and zinc on seed yield and quality of radish. Seed Res. 27(2): 154–158.

Singh, D.N. 2003. Effects of boron on the growth and yield of cauliflower in lateritic soil of western Orissa. Indian J. Hort. Sci. 60(3): 283–286.

Singh, G., S. Sarvanan, K.S. Rajawat, J.S. Rathore and G. Singh. 2017a. Effect of different micronutrients on plant growth, yield and flower bud quality of broccoli (*Brassica oleracea* var. *italica*). Curr. Agri. Res. 5(1): 108–115.

Singh, V., A.K. Singh, T. Raghuvanshi, M.K. Singh, V. Singh and U. Singh. 2017b. Influence of boron and molybdenum on growth, yield and quality of cauliflower (*Brassica oleracea* L. var. *botrytis*). Int. J. Curr. Microbiol. App. Sci. 6(10): 3408–3414.

Thakur, O.P., P.P. Sharma and K.K. Singh. 1991. Effect of nitrogen and phosphorus with and without boron on curd yield and stalk rot incidence in cauliflower. Veg. Sci. 18(2): 115–121.

Toth, S.J. and A.L. Prince. 1949. Estimation of cation-exchange capacity and exchangeable Ca, K, and Na contents of soils by flame photometer techniques. Soil Sci. 67(6): 439–446.

Yang, X., X.Y. Chen and Z.C. Liu. 2000. Effects of boron and molybdenum nutrition on curd yield and active oxygen metabolism in broccoli (*Brassica oleracea* var. *italica*). Acta Hortic. Sin. 27(2): 112–116.