EFFECT OF MICRONUTRIENTS AND MULCHING ON GROWTH AND YIELD OF BROCCOLI

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CERTIFICATE

This is to certify that the thesis entitled '**Effect of Micronutrients and Mulching on Growth and Yield of Broccoli**' submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in HORTICULTURE**, embodies the results of a piece of bonafide research work carried out by **Zannatul Abira**, Registration No. **09-03362** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2016
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TO

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ABSTRACT

The experiment was conducted in the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka during October 2015 to February 2016. The experiment consisted of two factors, such as Factor A: four levels of micronutrients i.e. T_0: No micronutrients, T_1: $Zn_{4.0}$ kg/ha, T_2: $Zn_{4.0}$ + $B_{1.5}$ kg/ha, T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha and Factor B: mulching materials (3 levels) as- M_0: No mulch (control), M_1: Water hyacinth, M_2: Black polythene. The two factorial experiment was laid out in Randomized Complete Block Design with three replications. Micronutrients and mulching influenced significantly on most of the parameters. In case of micronutrients, the highest curd yield (24.20 t/ha) was found from T_3 and the lowest curd yield (18.44 t/ha) was found from T_0. For mulching, M_2 performed the highest curd yield (25.23 t/ha) and the lowest (15.29 t/ha) was from M_0. For combined effect, the highest curd yield (28.76 t/ha) was obtained from T_3M_2 and the lowest curd yield (12.97 t/ha) from T_0M_0. The highest benefit cost ratio (2.14) was noted from the combination of T_3M_1 and the lowest benefit cost ratio (1.09) from T_0M_0. So, $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha micronutrients in presence of recommended $N_{120}P_{100}K_{150}S_{20}$ kg/ha fertilizer with water hyacinth mulch can be used for commercial broccoli production.

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SOME COMMONLY USED ABBREVIATIONS

FULL WORD	ABBREVIATION
Agro-Ecological Zone	AEZ
Bangladesh Bureau of Statistics	BBS
Bangladesh Rice Research Institute	BRRI
Co-efficient of variation	Cv
Days After Transplanting	DAT
and others	*et al.*
Etcetera	Etc
Food and Agriculture Organization	FAO
International Rice Research Institute	IRRI
Journal	J.
Least Significance Difference	LSD
Muriate of Potash	MoP
Parts per million	Ppm
Sher-e-Bangla Agricultural University	SAU
Soil Resources Development Institute	SRDI
Triple Superphosphate	TSP

Chapter 1

Introduction

CHAPTER I

INTRODUCTION

Broccoli (*Brassica oleracea* var. italica) is an important vegetable crop and has high nutritional and good commercial value (Yoldas *et al*., 2008). It is one of the most widely grown vegetable that consumed mostly all over the world (Pizetta *et al*., 2005), highlighted mainly for its nutritional value as a source of various compounds, such as vitamins, minerals, antioxidants, as well as its anticancer properties (Umar *et al*., 2013). The edible portion of the broccoli plant consists of tender stem and unopened flower buds. The plants form a kind of head consisting of green buds and thick fleshy flower stalk. The terminal head rather loose, green in color and the flower stalks are longer than cauliflower (Bose *et al*., 2002). It can be harvested for a wide period of time than cauliflower (Thompson and Kelly, 1988). Unlike cauliflower, broccoli produces smaller flowering shoots (secondary curds) from the leaf axils after harvest of main apical curds which are also edible.

The average yield of broccoli is low in Bangladesh compared to other countries of the world and the low yield of this crop however is not an indication of low yielding potentiality of this crop. However, low yield may be attributed to a number of reasons viz. unavailability of quality seeds of high yielding varieties, fertilizer management, disease and insect infestation and improper or limited irrigation facilities. Among different factors manure and fertilizer can play an important role for increasing the production of broccoli in Bangladesh (Manjit Singh, *et al*., 2011). Deficiency of soil nutrient is now considered as one of the major constraints to successful upland crop production in Bangladesh (Islam and Noor, 1982). Previous research has indicated that nutrients have important effects on broccolis productivity and quality (Belec *et al*., 2001; Moniruzzaman *et al*., 2007; Ambrosini *et al*., 2015).

Micronutrients play an important role in broccoli production. Among the micro elements, Zn, B and Mo play an important role directly and indirectly in improving the growth, yield and quality of broccoli in addition to checking various diseases and physiological disorders. Zinc (Zn) is responsible for many important physiological functions and is an essential nutrient for carbon metabolism in plant. Zinc is also involved in auxin productions. Under Zn deficiency, plasma membranes lose their integrity. B is one of the most widely applied micro-nutrients. It has different role in plants metabolic activities. Cell division, nitrogen and carbohydrate metabolism and water relation in plant are controlled by B. In its absence, nutritional disorders in vegetables like hollow stem in cauliflower and broccoli (Shelp, 1990). In Cole crops like cauliflower and broccoli, boron requirement is high (Mengal and Kirkby, 1987). Molybdenum is involved in several enzyme systems and is also required in the synthesis of ascorbic acid and is implicated in making iron physiologically available in plants.

Broccoli is cultivated in Bangladesh during the winter season when rainfall is scanty. In most of the time irrigation increase the cost of production resulting in unprofitable production of broccoli and make growers frustrated. Mulching can minimize the requirement of water and helps in retaining moisture (Amal *et al.* 1990). Mulches also reduce the water loss from the soil by evaporation and reduce the irrigation requirements (Prihar, 1986; Amal *et al.*, 1990 and Vanderwerken and Wilcox, 1988). Therefore, mulching may be helpful in conserving soil moisture of the preceding season and may be exploited to produce broccoli successfully particularly where rainfall and irrigation facilities are scarce. Mulching and fertilization influence the water and nutrient supply to the plant and can affect the nutritional composition of the harvested curd. Mulching increased minimum temperature of soil, accelerated plant height, early growth, early yield (Najafabadi *et al.*, 2012).

Under the above mention context and situation, the present experiment was conducted with the following objectives:

- To find out the effective of micronutrients (zinc, boron and molybdenum) combination on the yield contributing characters and yield of broccoli;
- To study the feasibility of producing broccoli by using mulching as an alternative of irrigation; and
- To observe the combined effects of different micronutrients and mulching for higher yield and economic return of broccoli.

Chapter 2

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Broccoli is a biennial, thermo sensitive herbaceous "Cole" crop in Bangladesh and the most widely grown vegetables in the temperate zones. Growth and curd development of broccoli are greatly influenced by growing environment. Many researchers have been noted different findings on this crop in different Journals and books. Some of the important and informative works and research findings related to different nutrients and mulching on broccoli so far been done at home and abroad have been reviewed in this chapter under the following headings-

2.1 Effect of different nutrients on broccoli

Silva *et al*. (2016) reported that proper growth and development of broccoli may be affected by the application of N and B. Accordingly, the objective herein was to verify the effects of N and B application on growth and the nutritional status in the vegetative phase of broccoli. The experimental design with four doses of B (0.25, 0.50, 1.00, and 2.00 mg dm-3) and two doses of N (200 and 600 mg dm-3), and the check treatment (no B and no N), with four repetitions. The green color index, the accumulation of N and B in the plant aerial part, leaf area, and the aerial part dry matter content were evaluated. The interaction between nitrogen and boron was not important for the green color index, N and B accumulation, leaf area and dry matter production of broccoli in the vegetative phase. However, the isolated effects of nitrogen fertilization and boron doses were beneficial for broccoli development.

The present investigation was carried out by Singh *et al*. (2015) to examine the optimum doses of NPK and boron application on broccoli in irrigated agro-ecosystem of western Uttar Pradesh. The results revealed significant response on growth and yield of broccoli for different treatments. Application of 120 kg N+60 kg P_2O_5+40 kg K_2O+15 kg B/ha gave maximum plant height (65.33 cm), number of leaves/plant (18.26), length longest leaf (52.99 cm), width of longest leaf (17.98 cm), spread of plant (55.53 cm) and stem diameter (4.47 cm), whereas in control was minimum pronounced plant height/plant (58.66 cm), number of leaves/plant (12.33), length longest leaf (42.70 cm) width of longest leaf (14.18 cm), spread of plant and stem diameter (3.04 cm). Similar, pattern on the curd diameter (13.69 cm), length of curd (16.33 cm), weight of curd/plant (286.89 g), weight of sprout/plant (126.89 g), weight of curd and sprout/plant (0.390 kg) and total yield Curd+sprout (148.51 q/ha) was recorded with the application of 120 kg N+60 kg P2O5+40 kg K2O+15 kg B/ha and minimum was under control treatment.

A field experiment was conducted by Giri *et al*. (2013) with the objective to determine the optimum rate of nitro- gen (N) fertilizer for effective growth and yield of two varieties of broccoli in southern plain of Nepal. The experiment was laid out with two varieties of broccoli (Calabrese and Green Sprouting) and five N rates (0, 50, 100, 150 and 200 kg ha^{-1}). The effects of variety and N rate on total curd yield were significant but the interaction effect was non significant. Green Sprouting produced 11% higher total curd than Calabrese. Similarly, curd production increased N rate up to 200 kg ha^{-1} reaching a maximum of 14.47 t ha^{-1}. This indicated that optimum level of N could be beyond the rates tested in this study, which needs further experimentation.

Firoz *et al*. (2008) carried out an experiment at the Hill Agricultural Research Station (HARS), Khagrachari. The trial was made in randomized complete block design with three replications. The treatment consisted of three broccoli varieties, viz., Green Commet, Green King and Green Harmony with three levels of boron viz., Control (0.0 kg/ha), l .0 kg/ha and 2.0 kg/ha. There was a significant and positive effect of boron application on the yield of the crop and 1.0 kg B/ha was found to be an optimum rate. The 1 .0 kg B/ha rate produced the highest yield (512.3g/plant) followed by 2.0 kg B/ha showing 508.5 g/plant and the B control did the lowest (445.4g/plant). All other characters remained unaffected by B application. However, the application of B at 1.0 kg/ha had the height curd weight (294.6 g) and 2.0 kg B showed the next result (270.2g).

A field experiment was conducted by Moniruzzaman *et al*. (2007) to find out the suitable doses of B and N for higher yield and good quality head of broccoli comprising with six levels of boron (B) (0. 0.5, 1, 1.5, 2 and 2.5 kg/ha) and two levels of nitrogen (N) (100 and 200 kg/ha) was conducted at the Agricultural Research Station, Raikhali, Rangamati Hill District during the winter (rabi) seasons. Boron application increased plant height, number of leaves per plant, length and width of the leaf, 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 N per hectare which was at par with 1.5 kg B plus 200 kg N per hectare and 1.5 kg B plus 100 kg N per hectare. The latter combination (1.5 kg B/ha + 100 kg N/ha) gave the lowest hollow stem in broccoli during both years. Response curve indicates 1.59 kg B/ha as optimum dose for this crop.

Zhang *et al*. (2007) carried out an experiment to study the effects of balanced application of nitrogen, phosphorous and potassium fertilizers on the growth and yield of broccoli at Nanjing Agricultural University in China. Treatments comprised: 0:0:0. 159.13:106.46:160.04, 348.81: 99.27: 160.08 and 371.35: 102.66: 172.04 kg N, P_2O_5 and K_2O, respectively. The growth and yield of broccoli showed marked improvement with the application of 160.08 and 371.35: 102.66: 172.04 kg N, P_2O_5 and K_2O, respectively.

A field experiment was conducted by Moniruzzaman *et al*. (2007) to find out the suitable doses of B and N for higher yield and good quality head of broccoli comprising with six levels of boron (B) (0. 0.5, 1, 1.5, 2 and 2.5 kg/ha) and two levels of nitrogen (N) (100 and 200 kg/ha) was conducted at the Agricultural Research Station, Raikhali, Rangamati Hill District during the winter (rabi) seasons. Nitrogen application at higher dose (200 kg/ha) also significantly gave higher values for all growth and yield attributes as well as yield. Maximum yield per hectare was obtained at 2 kg B plus 200 kg N per hectare which was at par with 1.5 kg B plus 200 kg N per hectare and 1.5 kg B plus 100 kg N per hectare.

An experiment was conducted by Brahma *et al*. (2006) to study the effect of nitrogen, phosphorous and potassium on growth and yield of broccoli cv. Pusa Broccoli KTS-1 at Assam Agricultural University in India during rabi season. Treatments comprised 0:0:0, 50:30:20, 100:60:40, 150:90:60 and 200:120:80 kg NPK/ha. The growth and yield of broccoli showed marked improvement with the application of 200:120:80 kg NPK/ha.

Singh and Singh (2004) reported that Zn application increased chlorophyll content and raised the concentration of Zn, Ca, Mg, K and P in tissues, whereas Na content decreased. Thus, Zn modified elemental composition of plant tissues favorably accelerated plant growth and yield.

A glass house experiments conducted by Annesar *et al.* (2004) with various macro and micro nutrients were carried out at Wiehenstephan, Bavaria. Broccoli was grown in plots with a black beltic peat substrate and reported that no deficiency symptoms were found for magnesium, iron, zinc, copper and manganese. Boron and Molybdenum deficiency and sodium chloride, boron, zinc and manganese over supplied caused severe damage.

Singh (2004) conducted a field experiment under different N and P levels (0, 60, 80 and 100 kg/ha) to evaluate the growth and yield of cauliflower cv. Snowball-16. Increasing P levels advanced curd initiation and maturity and increased plant height, leaf length, lead width, curd diameter, curd depth, net curd weight and marketable curd yield. There were no significant differences between between 80 and 100 kg P/ha. Application of 80 kg P/ha recorded the highest values for number of leaves per plant (19.44), curd diameter (16.42 cm), curd depth (10 cm), net curd weight (740.38 g), curd solidity (66.84 g/cm) and marketable curd yield (236.92 q/ha) as well as the highest net returns (Rs.101060/ha) and benefit cost ratio (6.81).

Brahma *et al.* (2002) carried out an experiment at Assam Agricultural University in India during rabi season to study the effect of nitrogen, phosphorus and potassium on growth and yield of broccoli cv. Pusa Broccoli KTS-1. Treatments comprised: 0:0:0, 50:30:20, 100:60:40, 150:90:60 and 200:120:80 kg NPK/ha. The growth and yield of broccoli showed marked improvement with the application of 200:120:80 kg NPK/ha.

Sharma *et al*. (2002) were conducted an experiment for assess the response of sprouting broccoli 'Green head' to different levels of N and P (30, 60 and 90 kg P_2O_5 /ha). They were found P are applied alone, maximum values with respects to plant height, plant frame, head size, head yield/plant and per hectare were obtained at 60 kg P_2O_5/ha respectively.

Field experiments were conducted by Singh (2002) with cauliflower (cv. Snowball-16) during the Rabi seasons of 1996-99 in Bihar, India. Four levels of B were applied at 0, 0.5, 1.0, and 2.0 kg/ha as Borax ($Na_2B_4O_7.10H_2O$), 11% (B) and band placed around each plant one week after transplanting. Soil application of B significantly produced higher marketable curd yields of cauliflower over the control in all three years. Application of B up to 1.0 kg/ha significantly increased the yields. Blackish curds appeared in the control plot. 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. The mean hot water soluble B in soil increased significantly from 0.47 to 0.83 mg/kg with increased rates of B application in soil from 0.5 to 2.0 kg/ha over the control (0.21 mg/kg).

Pardeep-Kumar *et al.* (2001) conducted an experiment on performance of different broccoli cultivars (Green Head, Palam Samridhi, DPGB 12 and American Selection) under different N, P and K rates (0, 0 and 0; 60, 45 and 15 kg/ha; 90, 60 and 30 kg/ha; 120, 75 and 45 kg/ha and 150, 90 and 60 kg/ha, respectively) in India and reported the maximum values for growth, yield and quality characteristics were obtained at the highest N, P and K levels (150, 90 and 60 kg/ha, respectively).

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

The effects of eight B-Mo treatments on curd yield and active oxygen metabolism in broccoli were studied by Xian *et al. (*2000) in South China Agricultural University. There was a close relationship between B-Mo nutrition and curd yield as well as active oxygen nutrition. There was a marked interaction between B and Mo nutrition. The combination of B and Mo at 5g /liter respectively increased and yield.

Consequently three field experiments were conducted by Castellanos *et al.* (1999) with broccoli on clay loam to clay soils. In the first two experiments, N was applied at 0-400 kg/ha in split application (20% at planting, 40% at 30 DAT and 40 at 45 DAT) together with 80 kg P_2O_5/ha and 300 kg K_2O/ha during transplanting. In the third experiment, N and K were injected into the drip irrigation system as determined by the demand curve and P was applied at planting. Among the experiment the third experiment, marketable yields were the highest (24.5 t/ha) at 400 kg N/ha.

Sumiati (1998) carried out an experiment and observed that seedlings of broccoli cultivars Green King and Mikado were transplanted into Jiffy pots or into a mixture of stable manure and soil supplemented or not supplemented with NPK compound fertilizer (15:15:15) and/or Metalik. There were differences between cultivars in plant height, root length, LAI, NAR and RGR at 2, 3 or 4 weeks after transplanting. These factors were all highest at all stages in plants grown in manures + soil supplement with NPK+ Metallic and were generally lowest in plants grown in jiffy pots.

A pot experiment was carried out by Ying *et al*. (1997) to determine the effect of N P and K on yield and quality of broccoli. Additive effects were observed on yield and vitamin C (ascorbic acid) content when K was applied together with N or N + P. Application of N + P gave 110.8% higher yields than N alone. From the findings they also suggested that N, P and K application should be balanced to obtain high yields and quality of broccoli.

Everates *et al.* (1997) conducted an experiment and found that application of a single dose of 260 kg N/ha (minus the amount of mineral N present in the top 0.60 cm layer of soil) by row application at the time of planting gave superior results. A high-yield crop uptook 200-250 kg N, 30 kg P and up to 250 kg K/ha.

Lu *et al.* (1997) observed tha nutrient absorption and dry matter accumulation of broccoli cultivars Green Valiant, Yuguan and Xinzengyanshui grown under routine fields fertilization and reported that the amounts of N, P, K, Ca and Mg were absorbed for every 1000 kg of broccoli heads were 15.45-20.60, 1.45-2.51, 8.98-10.87, 7.32-9.48 and 1.65-2.40 kg respectively.

Haque *et al.* (1996) observed that irrigation at 15, 30, 45% depletion of field capacity (FC) and nitrogen (60,120 and 180 g/ha) individually and combined had significance positive impact on growth and yield of broccoli at Bangladesh Sheikh Muzib Agricultural University, Gazipur, Bangladesh. The highest level of irrigation and nitrogen (irrigation at 15% depletion of FC with 180 kg N/ha) gave the highest yield (18.90 t/ha) and the lowest yield (3.29 t/ha) was recorded in the control plots, which received no irrigation or nitrogen. The treatment allowing 15 and 30% depletion of FC along with the application of nitrogen (120 and 180 kg/ha) were considered to the ones to obtain satisfactory yield (18.62 and 18.12 t/ha) of broccoli.

Yang and Guan (1995) recorded a close relationship between the texture and quality of the head and N, P and K nutrition. Rational application of nitrogen and potash fertilizers regulated the absorption of N, P and K by plants, promoted nitrate accumulation in leaves and spears, and increased spear yields.

Steffen *et al*. (1994) carried out an experiment and observed the effect organic matter (spent mushroom compost at 64 mt/ha + rotten cattle manure at 57 mt/ha) applied in spring on growth and yield of broccoli. No fertilizer or other amendments were added to previously amended treatments, but 100% recommended NPK be added to all control treatments. Broccoli yield and head diameter were greater in the amended treatment.

Simoes *et al*. (1993) investigated the effect of container size and substrate on growth and yield of broccoli in nursery and in field condition. It was found that containers of 21-31 mm wide and 71-75 mm deep, in combination with rich substrates (180-210 mg N, 120-240 mg P_2O_5 and 220-270 mg K_2O litre) produced the best result.

Magnifico *et al*. (1993) carried out a field trial on a silty clay soil at Policoro with broccoli, spinach, snap beans and pickling cucumbers grown in rotation comparing 12 NPK fertilizer rates and 3 herbicides (for each crop). Trifluralin, Chlorthal [-dimethyl] and Nitrofen were used on broccoli; Lenacil, Cyclote and Chlorbufam+Cycluron were applied on spinach; Trifluralin, Alachlor and Nitrofen were applied on snap beans; and Trifuralin, chlorthal and Asulam were applied on cucumbers. Over the 5 years, 17 crops were grown: 4 of broccoli, 3 of spinach, 5 of snap beans and 5 of cucumber. An average of 94 days were needed for broccoli, 85 for spinach, 65 for beans and 58 for cucumber, a total of 302 days/year. The effects of sowing/transplanting dates and harvesting and the residual effects of herbicides were examined. Yields of each species varied widely and were mainly influenced by fertilizer rates and not herbicides. Cucumber was the only crop to show phytotoxicity from herbicides used earlier on spinach. It was concluded that this intensive system could not be recommended to farmers since it required very careful planning and yields depended on a number of contingencies.

Bracy *et al*. (1992) conducted an experiment on direct-sown broccoli cv. Early dawn and the effects of pre-planting NPK fertilizer at a rate of 45 kg N+59 kg P +112 kg P and 90 kg N + 118 kg P +224 kg K/ha plus side dressed N fertilizer at 134, 196 or 258 kg/ha, either dropped onto or knifed into the bed were determined. The marketable yield, early yield, head weight and percentage of early to total yield were unaffected by fertilizer rate or method of application.

Mitra *et al*. (1990) obtained a yield of 51.5 tones broccoli/ha by applying nitrogen, phosphorus and potassium at the rate of 100, 50 and 50 kg/ha, respectively, compared with 33.5 tones/ha with 50 kg N, 25 kg P and 25 kg K/ha. They also reported that broccoli cv. Appollo produced average individual head weight of 0.87 lb by the application of N, P and K at the rate of 300, 100 and 150 kg/ha, respectively. In a field trials during the winter seasons Thakur *et al.* (1991) studied the effects of 5 rates of N application (80, 120, 160, 200 and 240 kg/ha), 4 rates of P application (100, 150, 200 and 250 kg/ha) and 2 rates of B application (0 and 20 kg/ha) on cauliflower cv. Pusa Snowball-1 were studied and reported that application of boron increased the number of leaves per plant, DM content and curd yield, and reduced leaf area, stalk length and incidence of stalk rot.

Shelp (1990) reported that Broccoli (cv. Premium Crop) seeds were germinated in soil, and the seedlings were transferred to vermiculite 3 weeks later and grown in a greenhouse; they were supplied continuously with B at concentration ranging from 0.0 to 12.5 mg/liter. At commercial maturity the partitioning of N into soluble (nitrate, ammonium, amino acids) and insoluble components of the foliage and the florets was investigated. Both B deficiency and toxicity increased the % soluble N, particularly as nitrate. Boron toxicity, but not deficiency consistently affected the concentration and relative amino acid composition, was dependent upon the developmental stage of the plant organs concerned, and upon whether B was present in deficient or toxic levels.

Magnifico *et al*. (1989) observed that the growth and accumulation of macro and microelements in various stages of the cultural cycle of 2 cultivars of broccoli in Southern Italy. Plant samples were obtained every 2 weeks beginning at the time of thinning and contenting for 112 and 126 days, respectively, for cultivars Di Gennaio and Di Marzo. Despite the different cultural cycle, the cultivars were similar in yield and element uptake. On a per hectare basis the plants removed about 460 kg N, 140 kg P_2O_5, 692 kg K_2O, 330 kg Ca, 75 kg Na, and 42 kg Mg. Microelement removal by Di Gennaio was 77 kg S, 20 kg Al, 12 kg Fe, 1 kg Mn, 479g Zn, 443 g Sr, 411 g B, 72 g Cu, 26 g Mo, 23 g Ni, and 20 g Ca. Total growth averaged 136-t/ha fresh materials, which included 14 t/ha of main heads, 28t/ha of secondary heads, and 14-t/ha dry matters. The highest removal rates were recorded from flower stem emission to main head production.

Dufault (1988) conducted an experiment to study the nitrogen and phosphorus requirements of greenhouse broccoli cv. Southern Comet and reported that increasing N rates increased head fresh weight, stem diameter, floret total chlorophyll, root and top dry weight (stem, petiole, leaf, and head), plant height, and head quality, and decreased days to heading and harvest. For quality broccoli production in greenhouse, 5.6 g N, 0.21 g P and 1.6 g K per 15-liter pot were required.

2.2 Effect of mulching on broccoli

The effects of soil mulching with rye, corn, rape and buckwheat straw at a dose of 10 and 20 t ha^{-1} on the yield and changes of selected components of nutritive value in 'Milady' F_1 broccoli and 'Polfast' F_1 tomato were investigated by Kosterna (2014). The effect of straw was compared to a control plot without mulch. The yield of the vegetables and their chemical composition depended to a higher degree on weather conditions in the years of study. 2010 was the most favourable for broccoli yielding and 2011 for tomato. More nutrients components in heads and fruits were found in 2011 and 2012, which were characterized by favourable rainfall distribution. All straws applied in the experiment, irrespective of dosage, caused an increase in broccoli yield. However, soil mulching with straw at a dose of 10 t ha^{-1} was better for tomato yielding. Soil mulching with rye, corn and buckwheat straw increased the share of marketable yield in the total yield of broccoli and rye straw as well as the share of marketable yield of tomato. Mulching with rape and buckwheat straw decreased dry matter content in the edible parts of the vegetables. Mulch with rye straw contributed to a decreased content of ascorbic acid in heads and fruits and also caused a slight reduction in tomato flesh acidity. However, soil mulching with corn and rape straw caused an increase in total sugars and monosaccharide content in broccoli and tomato.

Hashem (2005) carried out an experiment on effects of manuring and mulching on growth and yield of broccoli in BAU Mymensingh and observed that the maximum average yield (17.6 t/ha) was obtained from organic and inorganic fertilizers with black polythene mulch.

Ali (2004) carried out an experiment on effect of mulching and different levels of nitrogen on growth and yield of broccoli in BAU Mymensing and observed that the maximum average yield (16.4 t/ha) was obtained from 220 kg N/ha with black polythene mulch.

Santos *et al.* (2004) carried out an experiment with broccoli cultivars *Baron, Shigimori and pinacco* and found that the fresh mass of broccoli heads due to cultivation system were not significant except for *Shigimori* which recorded higher fresh mass when cultivated in open fields. The number of leaves per plant was higher under open field cultivation of *Shigimori and pinacco* and under non-woven propylene cultivation of boron. The longitudinal diameters of all the 3 cultivars were higher under open field cultivation compared to cultivation under non-woven propylene. The transverse diameters of broccoli were higher propylene cultivation of *piancco.*

Faruque (2002) carried out an experiment on effect of different sources of nutrients and mulching on growth and yield of broccoli in BAU Mymensingh and observed that the maximum average yield (18.2 t/ha) was obtained from organic+ inorganic fertilizer with black polythene mulch while minimum yield was given by (no fertilizer + no mulch + irrigation) treatment.

Runham *et al.* (2000) reported that paper mulch increases soil moisture levels non-irrigation courgettes but not in irrigated celery compared to non-covered soil. They also found that both paper and plastic mulch gave similar or higher head weight of broccoli. From another experiment with broccoli they conducted that soil temperature beneath the paper mulch was lower than both the non-mulched and black polythene-covered plots.

Over seeded legume living mulch did not affect broccoli yield in any site compared to the control plots and suppressed weeds as well as the site the oxyfluorofen in three of the four sites. Thus, the NT (no tillage) system used in these experiments could suppress weeds and produce high broccoli yield. Over seeded legume, living mulches could be established effectively after transplanting to suppress weeds without reducing broccoli yield (Infante and Morse, 1996).

Davies *et al.* (1993) conducted two field trial series conducted during 1990-1991 at Abernethy, file (Scotland), the effects were evaluated of using mulches to assist in weed control in broccoli cv. covet and shogun and Brussels sprouts cv Golfer. One trial examined novel mulches (smooth paper mulch, crimped paper mulch, bark, barley straw and black polythene) black polythene resulted in good weed control (with 0-1.0% ground covered weeds) and yield (4.08-4.93 kg/plot for broccoli and 7.05 kg for Brussels sprouts). The second trial evaluated the potential of using black and clear polythene mulches in vegetables to encourage weed germination, so dipping the seed bank, and to improve on normal stale seeded procedures, clear polythene improve weed germination, but there was farther germination after removal of the first flush. Black polythene increases yield from stale seeded values of 0.24-0.27 kg to 0.69-1.49 kg/plot.

Burnette *et al.* (1993) stated that N fertilizer increased the broccoli yield and black plastic mulched treatments tended to produce greater broccoli yield than unmulched treatment soil nitrate concentrations were higher throughout growing season in the mulched plots.

A trial with broccoli, convert, seed raised in soil blocks or modules. The seedlings were planted out on 18, April. The effects were compared with direct covered with perforated expanding plastic film to on covering until 13 May and 13 June. The cultivar Emperor was also included as root-ball (module-rasied) plants, covered by plastic untill30 May. With soil-block plants the plastic covers did not advance harvest, compared with non-covered plants but the harvest period was shortened by about 9 days. Covering until 40 May gave the highest yield amounting to 10.6 t/ha, compared with 6.8 t/ha for non-covered plants. Soil-block plants were harvested about 13 days earlier than root ball plants. With root-ball plants, covering did not enhance yield but about 3 or 4 days advanced harvest. The harvest period was also longer with covering. Emperor performed best, yielding about 6.5 t/ha with all 3 treatments (Brakeboer, 1990).

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted at the period of October 2015 to February 2016.

3.1.2 Experimental location

The present research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is $23^0 74^/$N latitude and $90^0 35^/$E longitude with an elevation of 8.2 meter from sea level.

3.1.3 Characteristics of soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ-28) and the General Soil Type is Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the study. The collected soil was air-dried, grind and passed through 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 have been presented in Appendix I.

3.1.4 Climatic condition

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix II. During this period the maximum temperature (26.5^0C) was recorded in the month of October 2015 while the minimum temperature (12.4^0C) in the month of January 2016. The highest humidity (81%) was recorded in the month of October, 2015, whereas the highest rainfall (30 mm) was recorded in the month of February 2016.

3.2 Experimental details

3.2.1 Planting materials

The seeds of broccoli (*Brassica oleracea var*. italica L.) cv. Green magic were used as planting materials for this experiment.

3.2.2 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Micronutrients (4 levels) as

i T_0: No micronutrients

ii. T_1: $Zn_{4.0}$ kg/ha

iii. T_2: $Zn_{4.0} + B_{1.5}$ kg/ha

iv. T_3: $Zn_{4.0} + B_{1.5} + Mo_{1.0}$ kg/ha

Recommended doses of $N_{120}P_{100}K_{150}S_{20}$ kg/ha were applied in all of the experimental plots.

Factor B: Mulching materials (3 levels) as

i. M_0: No mulch (control)

ii. M_1: Water hyacinth

iii. M_2: Black polythene

There were 12 (4 × 3) treatments combination such as T_0M_0, T_0M_1, T_0M_2, T_1M_0, T_1M_1, T_1M_2, T_2M_0, T_2M_1, T_2M_2, T_3M_0, T_3M_1 and T_3M_2.

3.2.3 Design and layout of the experiment

The two factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 299.04 m^2 with length 26.7 m and width 11.2 m which were divided into three equal blocks. Each block was divided into 12 plots where 12 treatments combination allotted at random. There were 36 unit plots and the size of each plot was 2.0 m × 1.8 m. The distance between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

3.2.4 Preparation of the main field

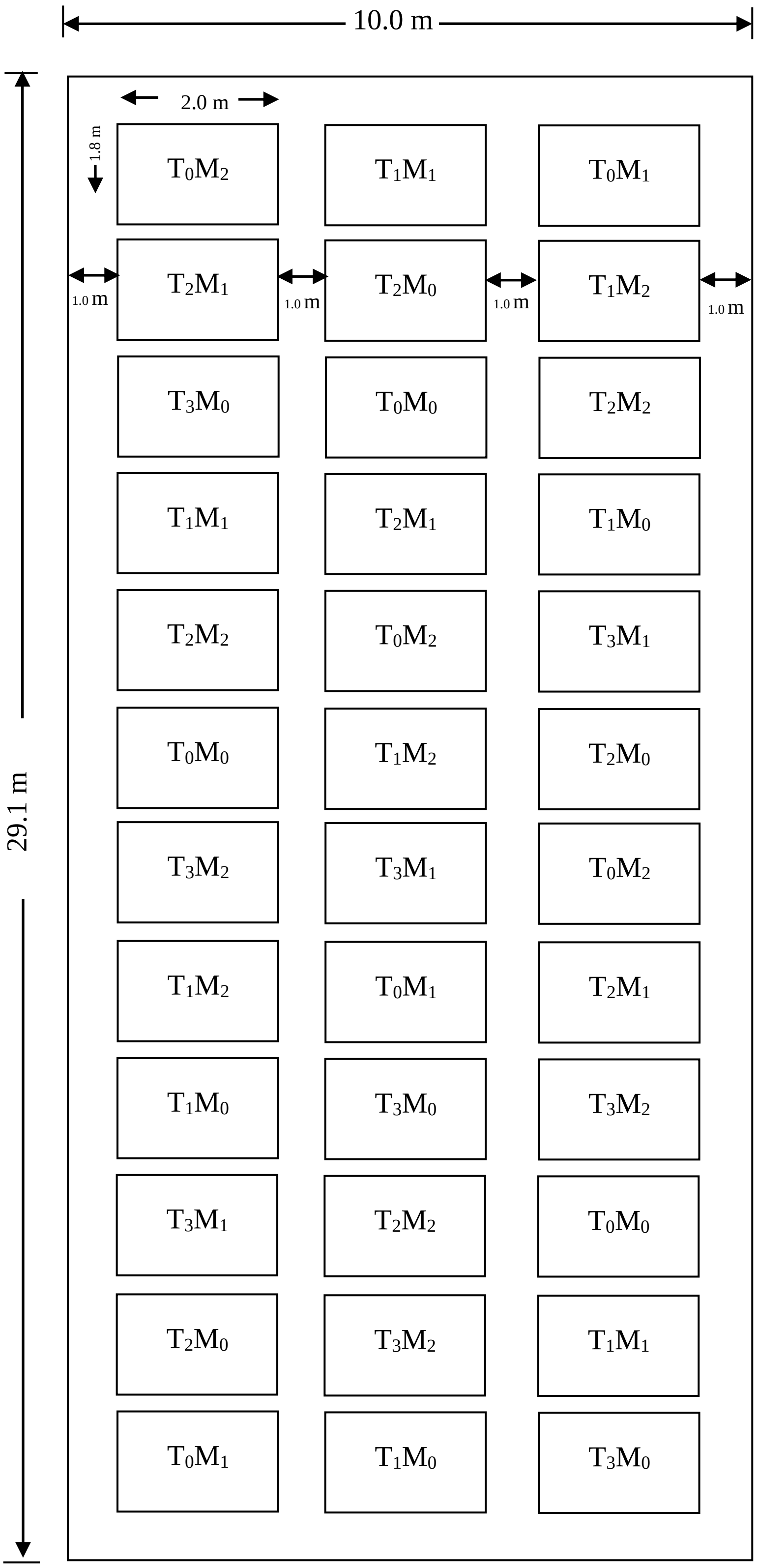
The selected plot of the experiment was opened in the 2nd week of November 2015 with a power tiller, and left exposed to the sun for a week. Subsequently cross ploughing was done five times with a country plough followed by laddering to make the land suitable for transplanting the seedlings. All weeds, stubbles and residues were eliminated from the field. Finally, a good tilth was achieved. 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.

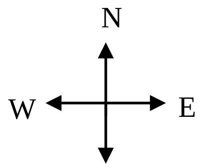
3.2.5 Application of manure and fertilizers

Urea, TSP, MoP, Gypsum were used as the fertilizer sources of nutrient elements N, P, K, S, respectively. A standard dose of NPKS @ 120, 100, 150, 20 kg/ha were used in all treatments. The following doses of manure and fertlizer were used for the present study.

Table 1. Dose and method of application of fertilizers in broccoli field

Fertilizers and Manures	Dose/ha	Application (%) at DAT			
		Basal	15	30	45
Cowdung	20 tonnes	100	--	--	--
Urea	260 kg (N: 120 kg)	--	33.33	33.33	33.33
TSP	208 kg (P: 100 kg)	100	--	--	--
MoP	250 kg (K: 150 kg)	--	33.33	33.33	33.33
Gypsum	20 kg (S: 20 Kg)	100	--	--	--
Zinc sulphate	11.4 kg (Zn: 4 kg)	100	--	--	--
Boric acid	8.80 kg (B: 1.5 kg)	100	--	--	--
Ammonium molybdate	1.85 kg (Mo: 1.0 kg)	100	--	--	--





Plot size: 2.0 m × 1.8 m

Plot spacing: 0.50 m

Between block: 1.00 m

Factor A: Micronutrients (4 levels):

i T_0: No micronutrients

ii. T_1: $Zn_{4.0}$ kg/ha

iii. T_2: $Zn_{4.0}$ + $B_{1.5}$ kg/ha

iv. T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha

Factor B: Mulching materials (3 levels):

i. M_0: No mulch (control)

ii. M_1: Water hyacinth

iii. M_2: Black polythene

Figure 1. Layout of the experimental plot

The total amount of cowdung, TSP and Gypsum was applied as basal dose at the time of land preparation. The total amount of urea and MoP was applied in three equal installments at 15, 30 and 45 day after transplanting.

3.2.6 Collection, preparation and application of micronutrients

Zinc as Zinc sulphate, Boron as boric acid and molybedenum as ammonium molybdate were collected from local market. Total 110.97 g zinc were appled in 27 zinc trated polt, whereas 57.15 g B were appled in 18 B treated plot and 6.0 mg Mo wre applied in 9 Mo treated plot as basal dose.

3.2.7 Application of mulching materials

Two types of mulching material; viz., water hyacinth and black polythene mulch were used. The fresh water hyacinth were chopped into small pieces (5 cm) and sun dried for three days before placing and black polythene sheet with small opening which was made for maintaining proper plant to plant and row to row distance before placing over the plots. The thickness of water hyacinth materials were maintained at 5 cm approximately.

3.3 Growing of crops

3.3.1 Collection of seeds

The seed of broccoli *Brassica oleracea* var. *italica* Green magic was collected from Siddique Bazar market, Dhaka.

3.3.2 Raising of seedlings

The seedlings were raised at the Horticultural Farm, SAU, Dhaka under special care in a 3 m × 1 m size seed bed. The soil of the seed bed was well ploughed with a spade and prepared into loose friable dried masses and to obtain good tilth to provide a favorable condition for the vigorous growth of young seedlings. Weeds, stubbles and dead roots of the previous crop were removed. The seedbed was dried in the sun to destroy the soil insect and protect the young seedlings from the attack of damping off disease. To control damping off disease Cupravit fungicide were applied. Decomposed cowdung was applied to the prepared seedbed at the rate of 10 t/ha. Ten (10) grams of seeds were sown in seedbed on October 8, 2015. After sowing, the seeds were covered with the finished light soil. At the end of germination shading was done by bamboo mat (chatai) over the seedbed to protect the young seedlings from scorching sunshine and heavy rainfall. Light watering, weeding was done as and when necessary to provide seedlings with ideal condition for growth.

3.3.3 Transplanting

Healthy and uniform seedlings of 20 days old seedlings were transplanting in the experimental plots on November 7, 2015. The seedlings were uploaded carefully from the seed bed to avoid damage to the root system. To minimize the damage to the roots of seedlings, the seed beds were watered one hour before uprooting the seedlings. Transplanting was done in the afternoon. The seedlings were watered immediately after transplanting. Seedlings were sown in the plot with maintaining distance between row to row was 60 cm and plant to plant was 40 cm. As a result there are 15 seedlings were accommodated in each plot according to the design of the plot size at 2.0 m × 1.8 m. The young transplanted seedlings were shaded by banana leaf sheath during day to protect them from scorching sunshine up to 7 days until they were set in the soil. They (transplants) were kept open at night to allow them receiving dew. A number of seedlings were also planted in the border of the experimental plots for gap filling.

3.3.4 Intercultural operation

After raising seedlings, various intercultural operations such as gap filling, weeding, earthing up, irrigation pest and disease control etc. were accomplished for better growth and development of the broccoli seedlings.

3.3.4.1 Gap filling

The transplanted seedlings in the experimental plot were kept under careful observation. Very few seedlings were damaged after transplanting and such seedling were replaced by new seedlings from the same stock. Replacement was done with healthy seedling having a boll of earth which was also planted on the same date by the side of the unit plot. The transplants were given shading and watering for 7 days for their proper establishment.

3.3.4.2 Weeding

The hand weeding was done 15, 30 and 45, 60 days after transplanting to keep the plots free from weeds.

3.3.4.3 Earthing up

Earthing up was done at 20 and 40 days after transplanting on both sides of rows by taking the soil from the space between the rows by a small spade.

3.3.4.4 Pest and disease control

Insect infestation was a serious problem during the period of establishment of seedling in the field. In spite of Cirocarb 3G applications during final land preparation, few young plants were damaged due to attack of mole cricket and cut worm. Cut worms were controlled both mechanically and spraying Darsban 29 EC @ 3%. Some plants were infected by *Alternaria* leaf spot diseases caused by *Alternaria brassicae*. To prevent the spread of the disease Rovral @ 2 g per liter of water was sprayed in the field. The diseased leaves were also collected from the infested plant and removed from the field. Birds pest such as nightingales (common Bulbuli) were seen visiting the broccoli field very frequently. The nightingale visited the fields in the morning and afternoon. The birds found to puncture the newly initiated curd and were controlled by striking a kerosene tin of metallic container frequently during day time.

3.4 Harvesting

Harvesting of the broccoli was not possible on a certain or particular date because the curd initiation as well as curd at marketable size in different plants were not uniform. Only the marketable size curds were harvested with fleshy stalk by using as sharp knife. Before harvesting of the broccoli curd, compactness of the curd was tested by pressing with thumbs.

3.5 Data collection

Five plants were randomly selected from the middle rows of each unit plot for avoiding border effect, except yields of curds, which was recorded plot wise. Data were collected in respect of the following parameters to assess plant growth; yield attributes and yields as affected by different treatments of this experiment. Data on plant height, number of leaves/plant, leaf length and length breadth were collected at 15, 30, 45 and 60 days after transplanting (DAT) and at harvest. All other yield contributing characters and yield parameters were recorded during harvest and after harvest.

3.5.1 Plant height (cm)

Plant height was measured from five randomly selected plants by using meter scale in centimeter from the ground level to the tip of the longest leaf at 15 days interval starting from 15 days after transplanting (DAT) and continued upto 60 DAT and at harvest and their mean value was calculated.

3.5.2 Number of leaves per plant

Number of leaves per plant was counted from five randomly selected plants at 15 days interval starting from 15 days after transplanting (DAT) and continued upto 60 DAT and at harvest and their average was recorded.

3.5.3 Leaf length (cm)

Leaf length was measured from five randomly selected plants in centimeter from lower level to the tip of the longest leaf and then average was calculated. Data were collected at 30, 45, 60 DAT and at harvest.

3.5.4 Leaf breadth (cm)

Leaf breadth was counted from five randomly selected plants at 15 days interval starting from 15 DAT and continued upto 60 DAT and at harvest and their mean value was find out.

3.5.5 Days to 1^{st} curd initiation

Each plant of the experiment plot was kept under close observation to assess days of curd initiation. Total number of days from the date of transplanting to the curd initiation was calculated and recorded.

3.5.6 Stem length (cm)

Stem length was taken from the ground level to base of the curd of plant during harvesting. A meter scale used to measure stem length and was expressed in centimeter (cm).

3.5.7 Stem diameter (cm)

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

3.5.8 Root length

Root length was measured from five randomly selected plant and their average were calculated and expressed in centimeter.

3.5.9 Root fresh weight per plant (g)

Root fresh weight per plant was recorded from five randomly selected plants in grams (gm) with a beam balance during harvest after detached from curd of broccoli and roots.

3.5.10 Primary curd weight (g)

The curds from sample plants were harvested, cleaned and weighted. Every primary curd were weighted in grams by weighing machine and mean values was counted.

3.5.11 Primary curd diameter (cm)

The curds from sample plants were sectioned vertically at the middle position with a sharp knife. The primary curd diameter was measured in centimeter (cm) with a meter scale as the horizontal distance from one side to another side of the widest part of the sectioned curd and mean value was recorded.

3.5.12 Number of secondary curds per plant

The total number of secondary curds per plant was counted from each selected plant. Data were recorded as the average of 5 plants selected at random of each plot at during harvest.

3.5.13 Secondary curds weight (g)

The secondary curds from sample plants were harvested, cleaned and weighted. The weight of every secondary curd from each plant was weighted by weighing machine and added them in plant wise and finally means values was calculated and recorded.

3.5.14 Dry matter content of curd (%)

At first curds of selected plant were collected, cut into pieces and was dried under sunshine for a 3 days and then dried in an oven at 70^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken. The dry matter contents of curd were computed by simple calculation from the weight recorded by the following formula:

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

3.5.15 Curd yield per plot (kg)

Curd yield per plot was recorded by multiplying average curd yield per plant with total number of plant within a plot and was expressed in kilogram and recorded plot wise.

3.5.16 Curd yield per hectare (t)

The curd yield per hectare was measured by converted total curd yield per plot into yield per hectare and was expressed in ton.

3.6 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance of the difference for different micronutrients and mulching on growth and yield contributing characters of broccoli. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the ‘F’ (variance ratio) test. The significance of the difference among the treatment combinations of means was estimated by Duncan’s Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

3.7 Economic analysis

The cost of production was analyzed in order to find out the most economic combination of different micronutrients and mulching for broccoli cultivation. 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 @ 12% in simple rate. The market price of broccoli was considered for estimating the cost and return. Analyses were done according to the procedure of Alam *et al*. (1989). The benefit cost ratio (BCR) was calculated as follows:

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

Chapter 4

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Plant height

The plant height of broccoli was varied significantly due to different micronutrients. It was recorded at 15, 30, 45, 60 DAT and at harvest (Appendix III). At harvest, the maximum plant height (67.58 cm) was recorded from T_3 ($Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha) treatment, which was statistically similar (65.46 cm) to T_2 ($Zn_{4.0}$ + $B_{1.5}$ kg/ha) treatment, whereas the shortest plant (61.76 cm) was found from T_0 (No micronutrients) treatment (Table 2). The result revealed that combined application of Zn, B, Mo was found to produced better growth of broccoli. It may be inferred that the increase in plant height may be done to the favorable influence and balanced absorption of nutrients. Similar results were also noted by Moniruzzaman *et al*. (2007). Singh *et al*. (2015) reported that application of 120 kg N+60 kg P_2O_5+40 kg K_2O+15 kg B/ha gave longest plant (65.33 cm).

Different mulching showed statistically significant variation in terms of plant height of broccoli at 15, 30, 45, 60 DAT and at harvest (Appendix III). At harvest, the highest plant height (68.18 cm) was observed from M_2 (Black polythene mulch) treatments which was statistically identical (67.29 cm) to M_1 (Water hyacinth mulch) treatment, while the shortest plant (59.11 cm) was recorded from M_0 (no mulch i.e. control condition) treatment (Table 3). In the present study black polythene mulching may accounted for retaining favorable maintain moisture and a more uniform temperature distribution in the soil than non mulch soil which making more nutrients elements available for promoted plants. Ali (2004) reported earlier longest plant as on effect of mulching in broccoli.

Table 2. Effect of different micronutrients on plant height at different days after transplanting (DAT) and at harvest of broccoli

Treatments	Plant height (cm) at				
	15 DAT	30 DAT	45 DAT	60 DAT	Harvest
T_0	17.49 c	34.45 c	48.29 c	54.39 c	61.76 c
T_1	19.14 b	36.50 b	51.13 b	58.62 b	64.52 b
T_2	20.33 a	37.87 ab	52.63 ab	59.62 ab	65.46 ab
T_3	21.41 a	39.23 a	54.56 a	61.72 a	67.58 a
$LSD_{(0.05)}$	1.187	1.479	1.979	2.991	2.719
CV(%)	6.19	4.09	5.93	5.22	4.29

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_0: No micronutrients

T_1: $Zn_{4.0}$ kg/ha

T_2: $Zn_{4.0} + B_{1.5}$ kg/ha

T_3: $Zn_{4.0} + B_{1.5} + Mo_{1.0}$ kg/ha

Table 3. Effect of different mulching on plant height at different days after transplanting (DAT) and at harvest of broccoli

Treatments	Plant height (cm) at				
	15 DAT	30 DAT	45 DAT	60 DAT	Harvest
M_0	17.15 b	33.42 b	46.70 b	55.22 b	59.11 b
M_1	20.49 a	38.18 a	53.74 a	59.82 a	67.29 a
M_2	21.15 a	39.45 a	54.22 a	60.77 a	68.18 a
$LSD_{(0.05)}$	1.028	1.281	1.714	2.590	2.355
CV(%)	6.19	4.09	5.93	5.22	4.29

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

M_0: No mulch

M_1: Water hyacinth mulch

M_2: Black polythene mulch

Combined effect of different micronutrients and mulching showed statistically significant differences on plant height of broccoli at 15, 30, 45, 60 DAT and at harvest (Appendix III). At harvest, the tallest plant (71.04 cm) was found from T_3M_2 ($Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha and black polythene mulch) treatment combination, which was statistically identical to T_3M_1 treatment combination and similar (68.73 cm) to T_3M_1 ($Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha and water hyacinth mulch) and T_2M_2 ($Zn_{4.0}$ + $B_{1.5}$ kg/ha and black polythene mulch), whereas the shortest plant (54.61 cm) was observed from T_0M_0 (No micronutrients and recommended dose of $N_{120}P_{100}K_{150}S_{20}$ kg/ha and no mulch) treatment combination (Table 4).

4.2 Number of leaves per plant

Statistically significant variation was recorded in terms of number of leaves per plant of broccoli due to different micronutrients at 15, 30, 45, 60 DAT and at harvest (Appendix IV). At harvest, the maximum number of leaves per plant (22.91) was found from T_3 treatment which was statistically similar (22.87) to T_2 treatment, while the minimum number of leaves per plant (21.38) was recorded from T_0 treatment (Figure 2). From the results of the present study indicate that, combined application of Zn, B and Mo kg/ha fertilizers might have induced better growing condition, perhaps due to supply of adequate plant nutrients, which ultimately had to produced more leaves per plant. Thakur *et al*. (1991) who reported that, application of boron increased the number of leaves per plant, dry matter (DM) content and curd yield and reduced leaf area, stalk length and incidence of stalk rot in broccoli.

Table 4. Combined effect of different micronutrients and mulching on plant height at different days after transplanting (DAT) and at harvest of broccoli

Treatments	Plant height (cm) at				
	15 DAT	30 DAT	45 DAT	60 DAT	Harvest
T_0M_0	15.29 e	31.44 g	44.45 f	49.72 e	54.61 d
T_0M_1	18.48 d	35.50 d-f	50.15 cd	55.85 cd	64.55 bc
T_0M_2	18.70 d	36.40 c-f	50.28 cd	57.60 b-d	66.43 ab
T_1M_0	18.34 d	34.57 ef	46.80 d-f	56.72 b-d	60.43 c
T_1M_1	19.47 cd	37.00 c-e	53.63 bc	59.51 a-d	66.60 ab
T_1M_2	19.62 cd	37.94 cd	52.97 bc	59.83 a-d	66.52 ab
T_2M_0	17.30 de	33.88 fg	46.34 ef	55.71 d	60.03 c
T_2M_1	21.14 bc	39.06 bc	54.61 ab	61.47 a-d	67.64 ab
T_2M_2	22.56 ab	40.68 ab	55.74 ab	61.69 a-c	68.73 ab
T_3M_0	17.67 d	33.77 fg	49.22 de	58.73 a-d	61.35 c
T_3M_1	22.85 ab	41.11 ab	56.58 ab	62.46 ab	70.36 a
T_3M_2	23.70 a	42.79 a	57.89 a	63.97 a	71.04 a
$LSD_{(0.05)}$	2.055	2.561	3.428	5.180	4.710
CV(%)	6.19	4.09	5.93	5.22	4.29

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_0: No micronutrients

T_1: $Zn_{4.0}$ kg/ha

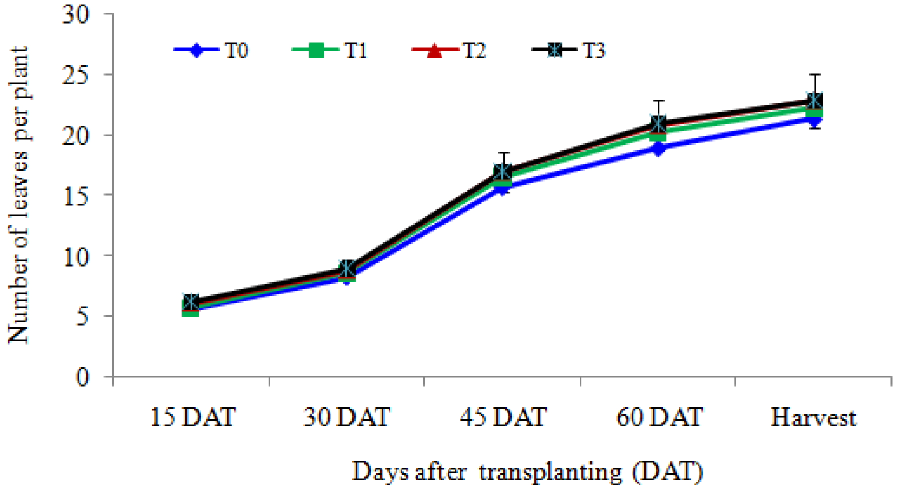
T_2: $Zn_{4.0}$ + $B_{1.5}$ kg/ha

T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha

M_0: No mulch

M_1: Water hyacinth mulch

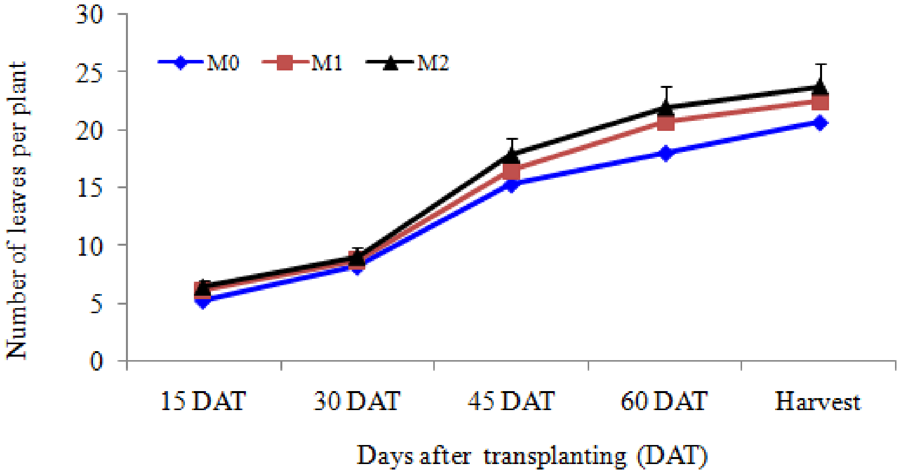
M_2: Black polythene mulch



T_0: No micronutrients; T_1: $Zn_{4.0}$ kg/ha;

T_2: $Zn_{4.0}$ + $B_{1.5}$kg/ha; T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha

Figure 2. Effect of different micronutrients on number of leaves per plant broccoli. (Vertical bars represent LSD value at 5% level of probability)



M_0: No mulch M_1: Water hyacinth mulch

M_3: Black polythene mulch

Figure 3. Effect of different mulching on number of leaves per plant of broccoli. (Vertical bars represent LSD value at 5% level of probability)

Number of leaves per plant of broccoli at 15, 30, 45, 60 DAT and at harvest showed statistically significant variation for different mulching (Appendix IV). At harvest, the maximum number of leaves per plant (23.83) was found from M_2 treatment which was statistically similar (22.52) to M_1 treatment, whereas the minimum number of leaves per plant (20.70) from M_0 treatment (Figure 3). It might be due to the retention of adequate soil moisture conserved properly by the black polythene mulch, which subsequently helped in increasing number of leaves per plant. This result supports the findings of Haque *et al*. (1996).

Combined effect of different micronutrients and mulching showed statistically significant differences on number of leaves per plant of broccoli at 15, 30, 45, 60 DAT and at harvest (Appendix IV). Data revealed that at harvest, the maximum number of leaves per plant (24.40) was found from T_3M_2 treatment combination, which was statistically similar (24.20, 24.00 and 23.33) to T_3M_1, T_2M_2 and T_2M_1 treatment combination, whereas the minimum number of leaves per plant (19.20) was recorded from T_0M_0 treatment combination (Table 5). Micronutrients combination with mulching might have improved the physical condition of soil which the increased moisture and nutrient availability in the soil and also balance the uptake of nutrients and physiological activities leading to increase the production of more leaves per plant of broccoli.

4.3 Leaf length

Leaf length of broccoli varied significantly due to different micronutrients at 15, 30, 45, 60 DAT and at harvest (Appendix V). At harvest, the longest leaf (43.90 cm) was found from T_3 treatment which was statistically similar (43.28 cm and 42.53 cm) to T_2 and to T_1 treatment, whereas the shortest leaf (39.48 cm) was recorded from T_0 treatment (Figure 4). The longest leaf per plant was achieved from T_3 treatment due to higher vegetative growth of plant. These result indicated that different micronutrients (Zn, B, Mo when used with NPKS fertilizers combinedly supplied balanced plant nutrients and provide better growing condition, which helped for getting proper vegetative growth as well as maximum length of leaf.

Table 5. Combined effect of different micronutrients and mulching on number of leaves per plant at different days after transplanting (DAT) and at harvest of broccoli

Treatments	Number of leaves per plant at				
	15DAT	30 DAT	45 DAT	60 DAT	Harvest
T_0M_0	4.73 d	7.80 e	13.93 e	16.20 e	19.20 d
T_0M_1	5.33 cd	8.27 c-e	16.07 cd	18.80 c-e	21.60 bc
T_0M_2	6.07 a-c	8.80 a-c	15.93 cd	20.07 b-d	21.53 bc
T_1M_0	5.67 bc	8.53 b-e	15.93 cd	18.47 c-e	20.60 cd
T_1M_1	6.33 ab	8.73 a-c	16.60 b-d	21.00 a-c	22.73 ab
T_1M_2	6.33 ab	8.53 b-e	17.20 a-c	21.47 ab	23.40 ab
T_2M_0	5.33 cd	7.87 de	15.13 de	17.87 de	20.20 cd
T_2M_1	6.47 a	8.87 a-c	17.20 a-c	21.53 ab	23.33 ab
T_2M_2	6.53 a	9.27 ab	17.47 a-c	21.87 ab	24.00 a
T_3M_0	5.40 cd	8.67 a-d	16.33 cd	19.67 b-d	22.80 ab
T_3M_1	6.60 a	9.40 ab	18.33 ab	23.07 a	24.20 a
T_3M_2	6.80 a	9.47 a	18.87 a	23.27 a	24.40 a
$LSD_{(0.05)}$	0.714	0.757	1.629	2.407	1.951
CV(%)	7.07	5.15	5.80	7.01	5.15

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_0: No micronutrients

T_1: $Zn_{4.0}$ kg/ha

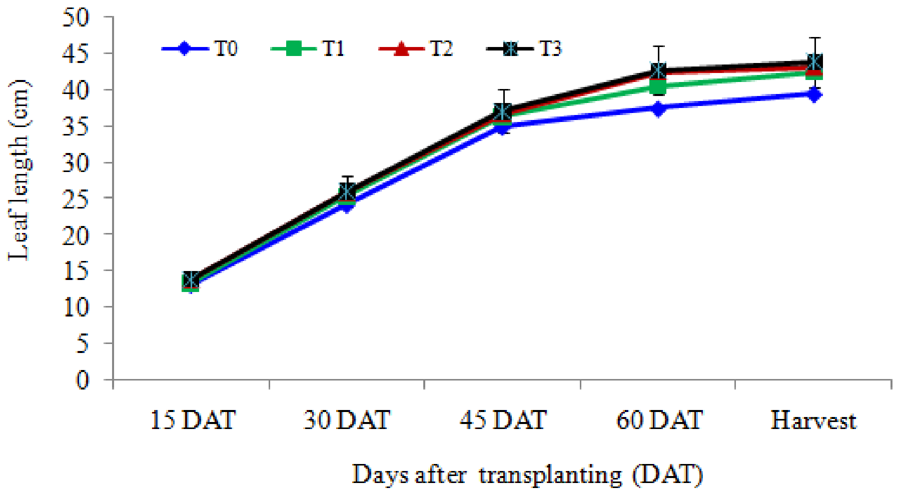
T_2: $Zn_{4.0} + B_{1.5}$ kg/ha

T_3: $Zn_{4.0} + B_{1.5} + Mo_{1.0}$ kg/ha

M_0: No mulch

M_1: Water hyacinth mulch

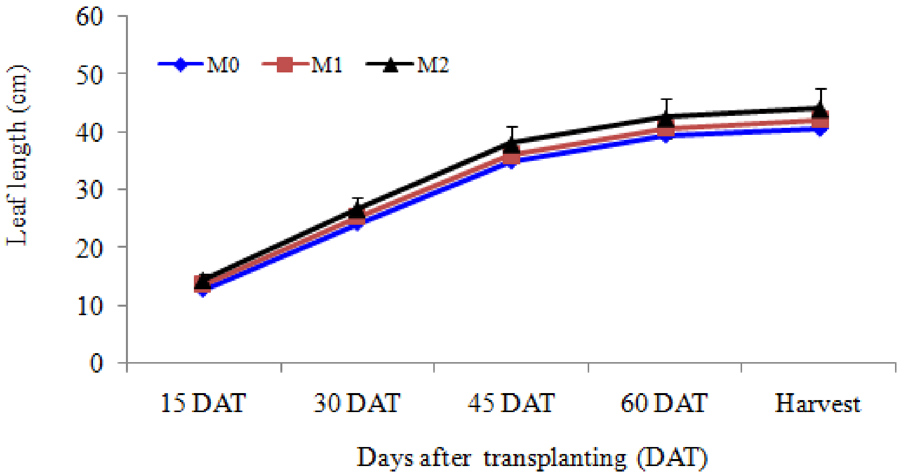
M_2: Black polythene mulch



T_0: No micronutrients; T_1: $Zn_{4.0}$ kg/ha;

T_2: $Zn_{4.0}$ + $B_{1.5}$ kg/ha; T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha

Figure 4. Effect of different micronutrients on leaf length of broccoli. (Vertical bars represent LSD value at 5% level of probability)



M_0: No mulch M_1: Water hyacinth mulch

M_3: Black polythene mulch

Figure 5. Effect of different mulching on leaf length of broccoli. (Vertical bars represent LSD value at 5% level of probability)

Different mulching showed statistically significant variation in terms of leaf length of broccoli at 15, 30, 45, 60 DAT and at harvest (Appendix V). At harvest, the longest leaf (44.11 cm) was found from M_2 treatment which was closely followed (42.22 cm) by M_1 treatment, whereas the shortest leaf (40.56 cm) was observed from M_0 treatment (Figure 5). This might be due to the fact that the black polythene mulching retention of moisture at the optimum levels and increase soil temperature, and suppressed weed growth effectively, which helped in increased maximum plant growth and increased leaf length of broccoli plant. Hashem (2005) observed that longest leaf from organic and inorganic fertilizers with black polythene mulch.

Statistically significant variation was recorded due to the combined effect of different micronutrients and mulching on leaf length of broccoli at 15, 30, 45, 60 DAT and at harvest (Appendix V). At harvest, the longest leaf (46.79 cm) was recorded from T_3M_2 which was statistically similar (45.76 cm), while the shortest leaf (37.46 cm) from T_0M_0 treatment combination (Table 6). Combined application of micronutrients and mulching probably lead to the production of larger leaves. Singh and Singh (2004) reported that Zn modified elemental composition of plant tissues favorable accelerated plant growth and yield.

4.4 Leaf breadth

Leaf breadth of broccoli varied significantly due to different micronutrients at 15, 30, 45, 60 DAT and at harvest (Appendix VI). At harvest, the highest leaf breadth (18.75 cm) was found from T_3 treatment which was statistically similar (18.47 cm) to T_2 treatment and (17.98 cm) by T_1 treatment, while the lowest leaf breadth (17.46 cm) was observed from T_0 treatment (Figure 6).

Significant variation was recorded due to different mulching on leaf breadth of broccoli at 15, 30, 45, 60 DAT and at harvest (Appendix VI). At harvest, the highest leaf breadth (19.18 cm) was recorded from M_2 treatment which was closely followed (18.30 cm) by M_1 treatment, while the lowest (17.01 cm) from M_0 treatment (Figure 7).

Table 6. Combined effect of different micronutrients and mulching on leaf length at different days after transplanting (DAT) and at harvest of broccoli

Treatments	Leaf length (cm) at				
	15 DAT	30 DAT	45 DAT	60 DAT	Harvest
T_0M_0	12.24 e	22.51 c	33.77 f	36.16 f	37.46 f
T_0M_1	13.70 cd	24.65 bc	35.59 c-f	37.88 ef	40.31 de
T_0M_2	13.47 cd	25.45 ab	35.49 c-f	38.38 ef	40.68 de
T_1M_0	12.98 c-e	24.78 bc	35.45 c-f	39.34 de	41.56 c-e
T_1M_1	13.47 cd	25.59 ab	34.52 d-f	41.32 cd	42.83 c-e
T_1M_2	13.87 c	25.76 ab	36.53 b-e	41.44 cd	43.05 b-e
T_2M_0	12.59 de	24.02 bc	34.01 ef	40.46 c-e	40.17 e
T_2M_1	13.32 c-e	25.89 ab	37.10 b-d	41.98 b-d	43.20 b-d
T_2M_2	14.04 bc	26.24 ab	37.54 bc	43.19 a-c	43.90 bc
T_3M_0	13.35 c-e	24.54 bc	36.64 b-e	40.55 c-e	41.86 c-e
T_3M_1	15.00 ab	27.61 a	39.06 ab	44.27 ab	45.76 ab
T_3M_2	15.18 a	27.81 a	40.25 a	45.83 a	46.79 a
$LSD_{(0.05)}$	1.037	2.242	2.369	2.594	2.569
CV(%)	4.50	5.21	7.85	3.74	6.59

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_0: No micronutrients

T_1: $Zn_{4.0}$ kg/ha

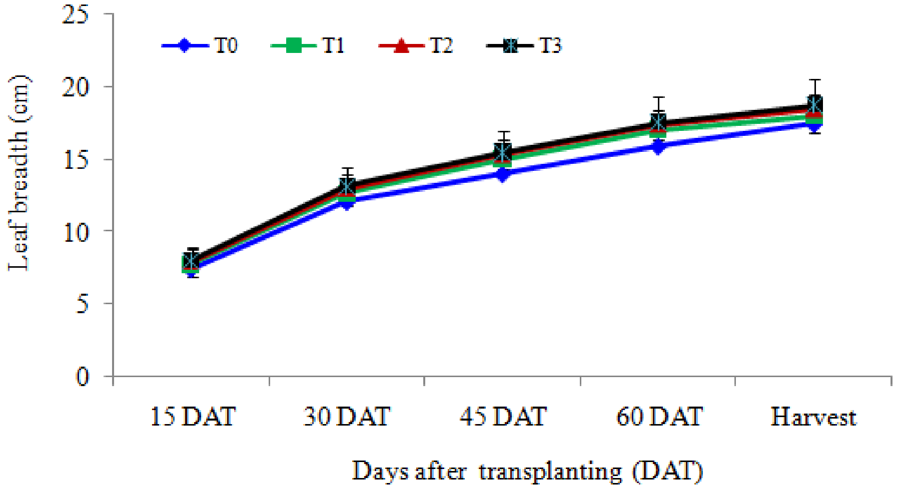
T_2: $Zn_{4.0}$ + $B_{1.5}$ kg/ha

T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha

M_0: No mulch

M_1: Water hyacinth mulch

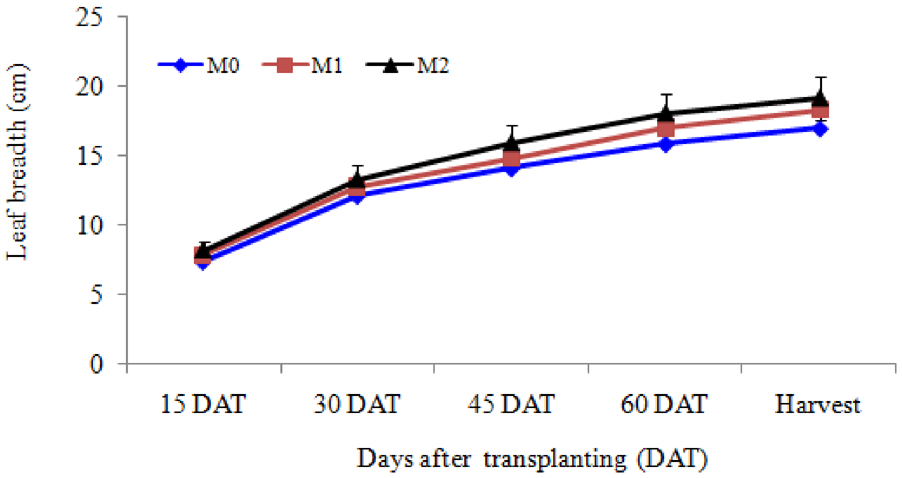
M_2: Black polythene mulch



T_0: No micronutrients; T_1: $Zn_{4.0}$ kg/ha;

T_2: $Zn_{4.0}$ + $B_{1.5}$ kg/ha; T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha

Figure 6. Effect of different micronutrients on leaf breadth of broccoli. (Vertical bars represent LSD value at 5% level of probability)



M_0: No mulch M_1: Water hyacinth mulch

M_3: Black polythene mulch

Figure 7. Effect of different mulching on leaf breadth of broccoli. (Vertical bars represent LSD value at 5% level of probability)

Combined effect of different micronutrients and mulching showed statistically significant differences on leaf breadth of broccoli at 15, 30, 45, 60 DAT and at harvest (Appendix VI). At harvest, the highest leaf breadth (20.27 cm) was found from T_3M_2 which was statistically similar (19.71 cm) to T_3M_1, whereas the shortest leaf breadth (16.27 cm) from T_0M_0 treatment combination (Table 7).

4.5 Days to 1st curd initiation

Days to 1st curd initiation varied significantly due to different micronutrients (Appendix VII). The maximum days to 1st curd initiation (60.11) was recorded from T_0 treatment, whereas the minimum days (56.11) was observed from T_3 treatment which was statistically similar (57.00 and 57.33 days) to T_2 treatment and T_1 treatment (Figure 8). The period requirement for curd initiation in plants decreased with combined application of Zn, B and Mo whereas the time was maximum when no Zn, B and Mo were applied. This might be due to the positive role played by the regulating Zn, B and Mo in balanced absorption of nutrition might improve physiological activities, which resulted the endogenous growth hormone synthesis responsible for early curd formation in plants.

Different mulching showed statistically significant variation in terms of days to 1st curd initiation (Appendix VII). The maximum days to 1st curd initiation (59.17) was observed from M_0 treatment, while the minimum days (55.92) was recorded from M_2 and the days to first curd initiation (57.83) was observed from M_1 treatment which was statistically similar to M_2 treatment and M_0 treatment (Figure 9). It might be black polythene mulch is highly effective in checking evaporation loss of soil moisture and also helps better utilization of applied fertilizer , which makes it suitable for proper growth and development of plant and finally minimum days required to curd formation.

Combined effect of different micronutrients and mulching showed statistically significant differences on days to 1st curd initiation of broccoli (Appendix VII). The maximum to 1st curd initiation (62.00) was found from T_0M_0, while the minimum days (50.33) from T_3M_2 treatment combination (Figure 10).

Table 7. Combined effect of different micronutrients and mulching on leaf breadth at different days after transplanting (DAT) and at harvest of broccoli

Treatments	Leaf breadth (cm) at				
	15 DAT	30 DAT	45 DAT	60 DAT	Harvest
T_0M_0	7.13 f	11.25 c	12.92 f	14.71 g	16.27 e
T_0M_1	7.61 d-f	12.31 bc	14.36 c-e	16.38 ef	17.96 d
T_0M_2	7.65 de	12.75 ab	14.74 c-e	16.71 de	18.15 cd
T_1M_0	7.54 def	12.24 bc	14.54 c-e	16.36 ef	17.64 d
T_1M_1	7.86 cd	12.87 ab	15.18 c-e	17.12 c-e	17.72 d
T_1M_2	7.86 cd	12.72 ab	14.15 d-f	16.72 de	18.22 cd
T_2M_0	7.16 ef	12.14 bc	13.79 ef	15.58 fg	16.37 e
T_2M_1	7.95 cd	12.88 ab	15.39 b-d	17.66 cd	18.58 b-d
T_2M_2	8.18 bc	13.23 ab	15.64 bc	17.87 bc	19.32 a-c
T_3M_0	7.61 d-f	12.92 ab	15.23 c-e	16.91 c-e	17.76 d
T_3M_1	8.57 ab	13.73 a	16.64 ab	18.78 ab	19.71 ab
T_3M_2	8.66 a	13.85 a	17.02 a	19.16 a	20.27 a
$LSD_{(0.05)}$	0.454	1.019	1.297	0.926	1.174
CV(%)	6.44	4.72	5.12	6.22	7.82

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_0: No micronutrients

T_1: $Zn_{4.0}$ kg/ha

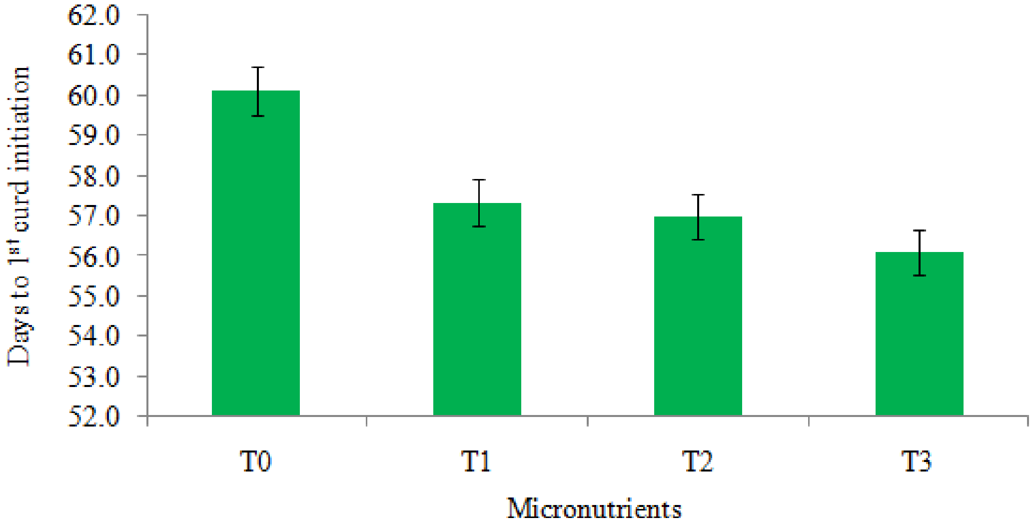
T_2: $Zn_{4.0}$ + $B_{1.5}$ kg/ha

T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha

M_0: No mulch

M_1: Water hyacinth mulch

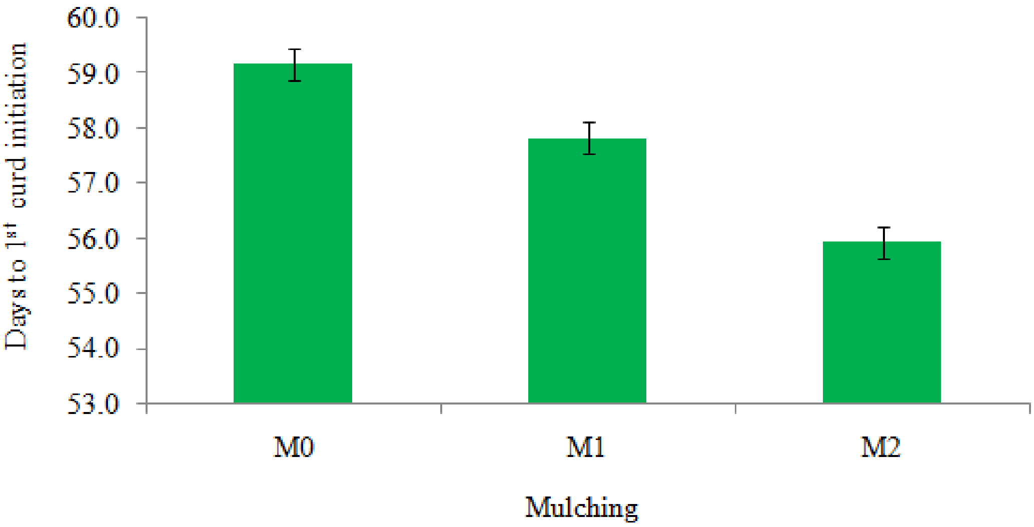
M_2: Black polythene mulch



T_0: No micronutrients; T_1: $Zn_{4.0}$ kg/ha;

T_2: $Zn_{4.0}$ + $B_{1.5}$kg/ha; T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha

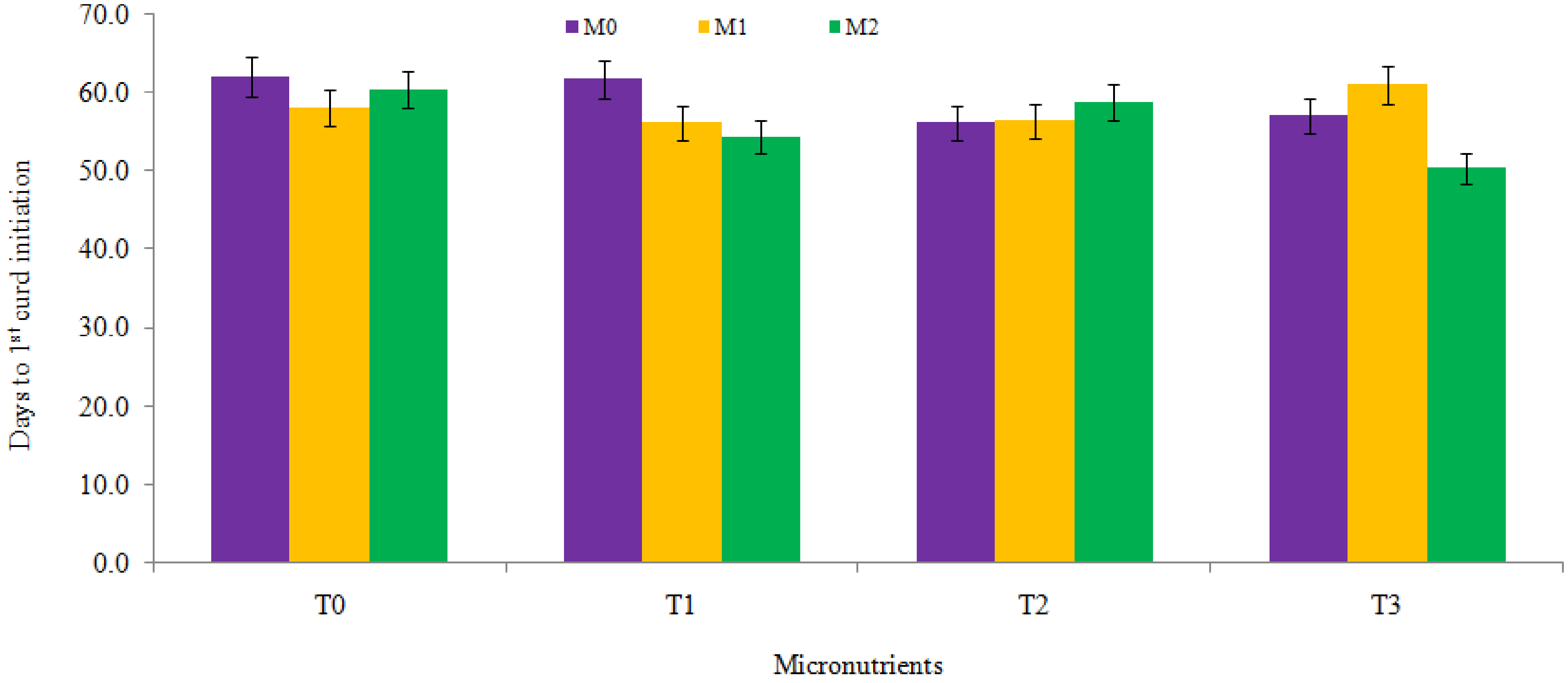
Figure 8. Effect of different micronutrients on days to 1st curd initiation of broccoli. (Vertical bars represent LSD value at 5% level of probability)



M_0: No mulch M_1: Water hyacinth mulch

M_3: Black polythene mulch

Figure 9. Effect of different mulching on days to 1st curd initiation of broccoli. (Vertical bars represent LSD value at 5% level of probability)



T_0: No micronutrients; T_1: $Zn_{4.0}$ kg/ha; M_0: No mulch M_1: Water hyacinth mulch

T_2: $Zn_{4.0}$ + $B_{1.5}$kg/ha; T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha M_3: Black polythene mulch

Figure 10. Effect of different micronutrients and mulching on days to 1st curd initiation of broccoli. (Vertical bars represent LSD value at 5% level of probability)

4.6 Stem length

Statistically significant variation was recorded for stem length of broccoli due to different micronutrients (Appendix VII). The longest stem (21.97 cm) was recorded from T_3 treatment which was statistically similar (21.42 cm) to T_2 treatment and closely followed (20.39 cm) by T_1 treatment, whereas the shortest stem (19.76 cm) was found from T_0 treatment (Table 8). From the results revealed that, combined application of Zn, B and Mo kg/ha fertilizers might have induced better growing condition, perhaps due to supply of adequate plant nutrients, which ultimately had to produced longest stem.

Different mulching showed statistically significant variation in terms of stem length of broccoli (Appendix VII). The longest stem (23.09 cm) was observed from M_2 treatment which closely followed (21.35 cm) by M_1 treatment, while the shortest stem (18.22 cm) was attained from M_0 treatment (Table 9). It might be due to the retention of adequate soil moisture conserved properly by the black polythene mulch, which subsequently helped in increasing stem length.

Combined effect of different micronutrients and mulching showed statistically significant differences on stem length of broccoli (Appendix VII). The longest stem (24.92 cm) was recorded from T_3M_2 treatment combination which was statistically similar (24.92 cm and 23.15 cm) to T_3M_1 and T_2M_2, whereas the shortest stem (17.57 cm) from T_0M_0 treatment combination (Table 10).

4.7 Stem diameter

Diameter of stem of broccoli varied significantly due to different micronutrients (Appendix VII). The highest stem diameter (2.92 cm) was recorded from T_3 treatment which was statistically similar (2.72 cm) to T_2 treatment and closely followed (2.55 cm) by T_1 treatment, whereas the lowest stem diameter (2.29 cm) was found from T_0 treatment (Table 8). Singh *et al*. (2015) reported the maximum stem diameter (4.47 cm), whereas in control condition it was minimum.

Table 8. Effect of different micronutrients on stem length, stem diameter, and roots length and roots fresh weight per plant of broccoli

Treatments	Stem length of (cm)	Stem diameter (cm)	Root length of (cm)	Roots fresh weight per plant (g)
T_0	19.76 c	2.29 c	21.96 b	30.10 b
T_1	20.39 bc	2.55 b	22.92 ab	30.87 ab
T_2	21.42 ab	2.72 ab	23.43 a	31.65 a
T_3	21.97 a	2.92 a	23.55 a	31.76 a
$LSD_{(0.05)}$	1.278	0.196	1.087	1.295
CV(%)	6.26	7.60	4.84	4.26

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_0: No micronutrients T_1: $Zn_{4.0}$ kg/ha

T_2: $Zn_{4.0}$ + $B_{1.5}$ kg/ha T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha

Table 9. Effect of different mulching on stem length, stem diameter, and roots length and roots fresh weight per plant of broccoli

Treatments	Stem length of (cm)	Stem diameter (cm)	Root length of (cm)	Roots fresh weight per plant (g)
M_0	18.22 c	2.35 c	20.65 c	29.90 c
M_1	21.35 b	2.59 b	23.13 b	31.07 b
M_2	23.09 a	2.92 a	25.12 a	32.32 a
$LSD_{(0.05)}$	1.106	0.169	0.941	1.122
CV(%)	6.26	7.60	4.84	4.26

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

M_0: No mulch M_1: Water hyacinth mulch

M_2: Black polythene mulch

Table 10. Combined effect of different micronutrients and mulching on stem length, stem diameter, and roots length and roots fresh weight per plant of broccoli

Treatments	Stem length of (cm)	Stem diameter (cm)	Root length of (cm)	Roots fresh weight per plant (g)
T_0M_0	17.57 f	2.16 f	19.48 g	28.56 e
T_0M_1	20.33 de	2.25 f	22.76 c-e	31.12 b-e
T_0M_2	21.37 c-e	2.46 d-f	23.64 cd	30.61 c-e
T_1M_0	19.25 ef	2.38 ef	21.41 e-g	30.92 c-e
T_1M_1	20.05 de	2.49 d-f	22.89 c-e	30.26 c-e
T_1M_2	21.85 b-d	2.68 c-e	22.36 de	30.43 c-e
T_2M_0	16.92 f	2.20 f	19.90 fg	28.99 de
T_2M_1	21.88 b-d	2.77 b-d	24.46 bc	31.43 a-d
T_2M_2	23.15 a-c	2.93 bc	24.52 bc	32.48 a-c
T_3M_0	19.15 ef	2.68 c-e	21.80 d-f	31.11 b-e
T_3M_1	24.18 ab	3.05 b	25.89 ab	33.49 ab
T_3M_2	24.92 a	3.39 a	26.49 a	33.74 a
$LSD_{(0.05)}$	2.213	0.339	1.883	2.243
CV(%)	6.26	7.60	4.84	4.26

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_0: No micronutrients

T_1: $Zn_{4.0}$ kg/ha

T_2: $Zn_{4.0}$ + $B_{1.5}$ kg/ha

T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha

M_0: No mulch

M_1: Water hyacinth mulch

M_2: Black polythene mulch

Different mulching showed statistically significant variation in terms of stem diameter of broccoli (Appendix VII). The highest stem diameter (2.92 cm) was found from M_2 treatment which closely followed (2.59 cm) by M_1 treatment and the lowest stem diameter (2.35 cm) was observed from M_0 treatment (Table 9). Hashem (2005) observed that highest stem diameter from organic and inorganic fertilizers with black polythene mulch.

Statistically significant variation was recorded due to combined effect of different micronutrients and mulching on stem diameter of broccoli (Appendix VII). The highest stem diameter (3.39 cm) was recorded from T_3M_2 which was closely followed (3.05 cm) by T_3M_1, whereas the lowest stem diameter (2.16 cm) from T_0M_0 treatment combination (Table 10).

4.8 Root length

Root length of broccoli varied significantly due to different micronutrients (Appendix VII). The longest root (23.55 cm) was found from T_3 treatment which was statistically similar (23.43 cm and 22.92 cm) to T_2 treatment and T_1 treatment, while the shortest root (21.96 cm) was recorded from T_0 treatment (Table 8). From the results of the present study indicate that, combined application of Zn, B and Mo kg/ha fertilizers might have induced better growing condition, perhaps due to supply of adequate plant nutrients, which ultimately had to produced longest root.

Statistically significant variation was recorded due to different mulching on length of root of broccoli (Appendix VII). The longest root (25.12 cm) was observed from M_2 treatment which closely followed (23.13 cm) by M_1 treatment, whereas the shortest root (20.65 cm) was observed from M_0 treatment (Table 9). Similar findings also reported by Santos *et al*. (2003). It might be due to the retention of adequate soil moisture conserved properly by the black polythene mulch, which subsequently helped in increasing root length.

Combined effect of different micronutrients and mulching showed statistically significant differences on length of root of broccoli (Appendix VII). Data reveled that the longest root (26.49 cm) was observed from T_3M_2 treatment combination which was statistically similar (25.89 cm) to T_3M_1 treatment combination, whereas the shortest root (19.48 cm) was observed from T_0M_0 treatment combination (Table 10).

4.9 Roots fresh weight per plant

Roots fresh weight per plant of broccoli varied significantly due to different micronutrients (Appendix VII). The highest roots fresh weight per plant (31.76 g) was found from T_3 treatment which was statistically similar (31.65 g and 30.87 g) to T_2 treatment and T_1 treatment, whereas the lowest roots fresh weight per plant (30.10 g) was found from T_0 treatment (Table 8).

Different mulching showed statistically significant variation in terms of fresh weight of roots per plant of broccoli (Appendix VII). The highest roots fresh weight per plant (32.32 g) was recorded from M_2 treatment which closely followed (31.07 g) by M_1 treatment and the lowest roots fresh weight per plant (29.90 g) was found from M_0 treatment (Table 9). Hashem (2005) observed maximum fresh weight of roots per plant from with black polythene mulch.

Combined effect of different micronutrients and mulching showed statistically significant differences on roots fresh weight per plant of broccoli (Appendix VII). The highest roots fresh weight per plant (33.74 g) was recorded from T_3M_2 treatment combination which was statistically similar (33.49 g and 32.48 g) to T_3M_1 and T_2M_2 treatment combination, whereas the lowest roots fresh weight per plant (28.56 g) from T_0M_0 treatment combination (Table 10).

4.10 Primary curd diameter

Primary curd diameter of broccoli varied significantly due to different micronutrients (Appendix VIII). The highest primary curd diameter (9.26 cm) was recorded from T_3 treatment which was statistically (9.02 cm 8.79 cm) to T_2 treatment and T_1 treatment, while the lowest primary curd diameter (8.31 cm) from T_0 treatment (Table 11). It might be due to the fact that lack of Zn, B and Mo renders the plants incapable of up taking the nutrients for normal growth and development. The combination of Zn, B and Mo probably leads to better performance of the crop resulting in the production of maximum curd diameter.

Statistically significant variation was recorded due to different mulching on primary curd diameter of broccoli (Appendix VIII). The highest primary curd diameter (9.22 cm) was observed from M_2 treatment which was statistically similar (8.97 cm) to M_1 treatment and the lowest primary curd diameter (8.35 cm) was recorded from M_0 treatment (Table 12). These results indicate that black polythene create favorable condition for the growth of plant effectively, which leads to production of the maximum diameter of curd that control.

Combined effect of different micronutrients and mulching showed statistically significant differences on primary curd diameter of broccoli (Appendix VIII). The highest diameter of primary curd (9.68 cm) was recorded from T_3M_2 which was statistically similar (9.53 cm) to T_3M_1, whereas the lowest primary curd diameter (8.07 cm) from T_0M_0 treatment combination (Table 13).

4.11 Primary curd weight

Statistically significant variation was recorded for primary curd weight of broccoli due to different micronutrients (Appendix VIII). The highest primary curd weight (492.05 g) was recorded from T_3 treatment which was closely followed (464.12 g) by T_2 treatment, whereas the lowest primary curd weight (396.10 g) was found from T_0 treatment which was followed (445.54 g) by T_1 treatment (Table 11). It might be that the combined application of Zn, B and Mo increases the rate of photosynthesis and facilities the transport of carbohydrates through cell membranes. Zn also influenced increasing the uptake of N and K resulting higher curd weight. Xian *et al*. (2000) who reported that there was a close relationship between B and Mo nutrition and curd yields the combination of B and Mo at 5 g/L, respectively increased yield. Firoz *et al*. (2008) reported that the application of B at 1.0 kg/ha had the height curd weight (294.6 g) and 2.0 kg B showed the next result (270.2 g).

Table 11. Effect of different micronutrients on primary curd diameter and primary curd weight and secondary curd number and secondary curd weight of broccoli

Treatments	Primary curd diameter (cm)	Primary curd weight (g)	Number of secondary curd per plant	Secondary curd weight (g)
T_0	8.31 b	396.10 d	2.54 d	60.91 d
T_1	8.79 a	445.54 c	2.72 c	66.95 c
T_2	9.02 a	464.12 b	2.88 b	70.91 b
T_3	9.26 a	492.05 a	3.03 a	75.50 a
$LSD_{(0.05)}$	0.455	14.63	0.076	1.951
CV(%)	5.27	5.33	6.85	4.91

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_0: No micronutrients

T_1: $Zn_{4.0}$ kg/ha

T_2: $Zn_{4.0}$ + $B_{1.5}$ kg/ha

T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha

Table 12. Effect of different mulching on primary curd diameter and primary curd weight and secondary curd number and secondary curd weight of broccoli

Treatments	Primary curd diameter (cm)	Primary curd weight (g)	Number of secondary curd per plant	Secondary curd weight (g)
M_0	8.35 b	329.16 c	2.35 c	55.00 c
M_1	8.97 a	501.49 b	2.94 b	73.87 b
M_2	9.22 a	517.71 a	3.09 a	76.83 a
$LSD_{(0.05)}$	0.394	12.67	0.066	1.689
CV(%)	5.27	5.33	6.85	4.91

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

M_0: No mulch

M_1: Water hyacinth mulch

M_2: Black polythene mulch

Table 13. Combined effect of different micronutrients and mulching on primary curd diameter and primary curd weight and secondary curd number and secondary curd weight of broccoli

Treatments	Primary curd diameter (cm)	Primary curd weight (g)	Number of secondary curd per plant	Secondary curd weight (g)
T_0M_0	8.07 e	281.35 f	2.17 g	49.78 h
T_0M_1	8.23 c-e	449.70 d	2.70 d	65.04 e
T_0M_2	8.64 b-e	457.26 d	2.77 d	67.92 e
T_1M_0	8.16 de	341.14 e	2.33 f	54.29 g
T_1M_1	9.01 a-d	494.23 c	2.83 d	72.21 d
T_1M_2	9.09 a-c	501.25 c	3.00 c	74.36 cd
T_2M_0	8.18 de	342.03 e	2.50 e	55.94 g
T_2M_1	9.21 ab	507.67 c	3.00 c	76.27 c
T_2M_2	9.33 ab	542.67 b	3.13 b	80.52 b
T_3M_0	9.00 a-d	352.13 e	2.40 ef	60.00 f
T_3M_1	9.53 ab	554.36 ab	3.23 b	81.96 ab
T_3M_2	9.68 a	569.66 a	3.47 a	84.54 a
$LSD_{(0.05)}$	0.789	25.34	0.131	3.379
CV(%)	5.27	5.33	6.85	4.91

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_0: No micronutrients

T_1: $Zn_{4.0}$ kg/ha

T_2: $Zn_{4.0}$ + $B_{1.5}$ kg/ha

T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha

M_0: No mulch

M_1: Water hyacinth mulch

M_2: Black polythene mulch

Different mulching showed statistically significant variation in terms of weight of primary curd of broccoli (Appendix VIII). The highest primary curd weight (517.71 g) was observed from M_2 treatment which closely followed (501.49 g) by M_1 treatment, while the lowest primary curd weight (329.16 g) was recorded from M_0 treatment (Table 12). Drastic fluctuation in soil temperature during severe winter period can be checked by black polythene mulch which help to increasing curd weight.

Combined effect of different micronutrients and mulching showed statistically significant differences on primary curd weight of broccoli (Appendix VIII). The highest primary curd weight (569.66 g) was found from T_3M_2 which was statistically similar (554.36 g) to T_3M_1, whereas the lowest primary curd weight (281.35 g) was observed from T_0M_0 treatment combination (Table 13).

4.12 Number of secondary curd per plant

Statistically significant variation was recorded for number of secondary curd per plant of broccoli due to different micronutrients (Appendix VIII). The maximum number of secondary curd per plant (3.03) was observed from T_3 treatment which was closely followed (2.88) by T_2 treatment, whereas the minimum number of secondary curd per plant (2.54) was found from T_0 treatment which was followed (2.72) by T_1 treatment (Table 11). It was revealed that, combined application of Zn, B and Mo kg/ha fertilizers might have induced better growing condition, perhaps due to supply of adequate plant nutrients, which ultimately had to produced more number of secondary curd per plant.

Different mulching showed statistically significant variation in terms of number of secondary curd per plant of broccoli (Appendix VIII). The maximum number of secondary curd per plant (3.09) was found from M_2 treatment which was closely followed (2.94) by M_1 treatment, while the minimum number of secondary curd per plant (2.35) was recorded from M_0 treatment (Table 12). It might be due to the retention of adequate soil moisture conserved properly by the black polythene mulch, which subsequently helped in increasing number of secondary curd per plant.

Combined effect of different micronutrients and mulching showed statistically significant differences on number of secondary curd per plant of broccoli (Appendix VIII). The maximum number of secondary curd per plant (3.47) was found from T_3M_2 which was closely followed (3.23 and 3.13) by T_3M_1 and T_2M_2, whereas the minimum number of secondary curd per plant (2.17) was observed from T_0M_0 treatment combination (Table 13).

4.13 Secondary curd weight

Secondary curd weight of broccoli varied significantly due to different micronutrients (Appendix VIII). The highest secondary curd weight (75.50 g) was observed from T_3 treatment which was closely followed (70.91 g) by T_2 treatment, while the lowest secondary curd weight (60.91 g) was recorded from T_0 treatment which was followed (66.95 g) by T_1 treatment (Table 11). It was revealed that, combined application of Zn, B and Mo kg/ha fertilizers might have induced better growing condition, perhaps due to supply of adequate plant nutrients, which ultimately had to produced highest secondary curd weight.

Different mulching showed statistically significant variation in terms of secondary curd weight of broccoli (Appendix VIII). The highest secondary curd weight (76.83 g) was found from M_2 treatment which was closely followed (73.87 g) by M_1 treatment, whereas the lowest secondary curd weight (55.00 g) was observed from M_0 treatment (Table 12). It might be due to the retention of adequate soil moisture conserved properly by the black polythene mulch, which subsequently helped in increasing secondary curd weight.

Statistically significant variation was recorded due to combined effect of different micronutrients and mulching on secondary curd weight of broccoli (Appendix VIII). The highest secondary curd weight (84.54 g) was recorded from T_3M_2 which was statistically similar (81.96 g) to T_3M_1, while the lowest weight (49.78 g) was found from T_0M_0 treatment combination (Table 13).

4.14 Dry matter content of curd

Statistically significant variation was recorded of dry matter content of curd of broccoli due to different micronutrients (Appendix IX). The highest dry matter content of curd (13.80 g) was found from T_3 treatment which was statistically identical (13.77 g and 13.53 g) to T_2 treatment and similar to T_1 treatment, while the lowest dry matter content of curd (13.10 g) was observed from T_0 treatment, which was statistically similar to T_1 treatment (Table 14). Thakur *et al.* (1991) reported that application of boron increased DM content and curd yield.

Different mulching showed statistically significant variation in terms of dry matter content of curd (Appendix IX). The highest dry matter content of curd (13.89 g) was found from M_2 treatment which was statistically similar (13.53 g) to M_1 treatment and the lowest dry matter content of curd (13.23 g) from M_0 treatment which was statistically similar to M_1 treatment (Table 15).

Combined effect of different micronutrients and mulching showed statistically significant differences on dry matter content of curd of broccoli (Appendix IX). The highest dry matter content of curd (14.28 g) was found from T_3M_2 which was statistically similar to all of the treatment combination except T_0M_0 and T_2M_0, whereas the lowest dry matter content of curd (12.59 g) was found from T_0M_0 treatment combination (Table 16).

4.15 Curd yield per plot

Curd yield/plot of broccoli varied significantly due to different micronutrients (Appendix IX). Data reveled that the highest curd yield per plot (8.71 kg) was observed from T_3 treatment which was closely followed (8.05 kg) by T_2 treatment, while the lowest curd yield per plot (6.64 kg) was recorded from T_0 treatment which was followed (7.56 kg) by T_1 treatment (Table 14). It was revealed that, combined application of Zn, B and Mo kg/ha fertilizers might have induced better growing condition, perhaps due to supply of adequate plant nutrients, which ultimately had to produced highest curd yield per plant.

Table 14. Effect of different micronutrients on dry matter content in curd and yield per plot and hectare of broccoli

Treatments	Dry matter content of curd (%)	Curd yield per plot (kg)	Curd yield per hectare (ton)
T_0	13.10 b	6.64 d	18.44 d
T_1	13.53 ab	7.56 c	21.01 c
T_2	13.77 a	8.05 b	22.37 b
T_3	13.80 a	8.71 a	24.20 a
$LSD_{(0.05)}$	0.511	0.196	0.546
CV(%)	3.86	5.60	5.60

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_0: No micronutrients

T_1: $Zn_{4.0}$ kg/ha

T_2: $Zn_{4.0} + B_{1.5}$ kg/ha

T_3: $Zn_{4.0} + B_{1.5} + Mo_{1.0}$ kg/ha

Table 15. Effect of different mulching on dry matter content in curd and yield per plot and hectare of broccoli

Treatments	Dry matter content of curd (%)	Curd yield per plot (kg)	Curd yield per hectare (ton)
M_0	13.23 b	5.51 c	15.29 c
M_1	13.53 ab	8.64 b	24.00 b
M_2	13.89 a	9.08 a	25.23 a
$LSD_{(0.05)}$	0.442	0.169	0.473
CV(%)	3.86	5.60	5.60

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

M_0: No mulch

M_1: Water hyacinth mulch

M_2: Black polythene mulch

Table 16. Combined effect of different micronutrients and mulching on dry matter content in curd and yield per plot and hectare of broccoli

Treatments	Dry matter content of curd (%)	Curd yield per plot (kg)	Curd yield per hectare (ton)
T_0M_0	12.59 c	4.67 g	12.97 g
T_0M_1	13.27 a-c	7.50 e	20.84 e
T_0M_2	13.43 a-c	7.74 e	21.51 e
T_1M_0	13.43 a-c	5.61 f	15.59 f
T_1M_1	13.55 a-c	8.39 d	23.29 d
T_1M_2	13.37 a-c	8.69 cd	24.14 cd
T_2M_0	13.16 bc	5.78 f	16.06 f
T_2M_1	13.76 ab	8.84 c	24.56 c
T_2M_2	13.93 ab	9.54 b	26.50 b
T_3M_0	13.62 ab	5.95 f	16.54 f
T_3M_1	14.23 a	9.83 b	27.31 b
T_3M_2	14.28 a	10.35 a	28.76 a
$LSD_{(0.05)}$	0.885	0.339	0.946
CV(%)	3.86	5.60	5.60

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_0: No micronutrients

T_1: $Zn_{4.0}$ kg/ha

T_2: $Zn_{4.0} + B_{1.5}$ kg/ha

T_3: $Zn_{4.0} + B_{1.5} + Mo_{1.0}$ kg/ha

M_0: No mulch

M_1: Water hyacinth mulch

M_2: Black polythene mulch

Statistically significant variation was recorded for different mulching on curd yield per plot (Appendix IX). The highest curd yield per plot (9.08 kg) was found from M_2 treatment which closely followed (8.64 kg) by M_1 treatment and the lowest curd yield per plot (5.51 kg) from M_0 treatment (Table 15). It might be due to the retention of adequate soil moisture conserved properly by the black polythene mulch, which subsequently helped in increasing curd yield per plot.

Curd yield per plot of broccoli showed statistically significant differences due to combined effect of different micronutrients and mulching (Appendix IX). The highest curd yield per plot (10.35 kg) was recorded from T_3M_2 which was closely followed (9.83 kg and 9.54 kg) by T_3M_1 and T_2M_2, whereas the lowest curd yield per plot (4.67 kg) from T_0M_0 treatment combination (Table 16).

4.16 Curd yield per hectare

Different micronutrients varied significantly in terms of curd yield per hectare of broccoli (Appendix IX). The highest curd yield/hectare (24.20 ton) was recorded from T_3 treatment which was closely followed (22.37 ton) by T_2 treatment, whereas the lowest curd yield per hectare (18.44 ton) from T_0 which was followed (21.37 ton) by T_1 treatment (Table 14). Zhang *et al.* (2007) reported that the yield of broccoli showed marked improvement with the application of different fertilizers. Moniruzzaman *et al.* (2007) reported maximum yield per hectare was obtained at 2 kg B plus 200 kg N per hectare which was at par with 1.5 kg B plus 200 kg N per hectare and 1.5 kg B plus 100 kg N per hectare.

Different mulching showed statistically significant variation in terms of curd yield per hectare (Appendix IX). The highest curd yield per hectare (25.23 ton) was found from M_2 treatment which closely followed (24.00 ton) by M_1 treatment, while the lowest curd yield per hectare (15.29 ton) was observed from M_0 treatment (Table 15). It might be due to the retention of adequate soil moisture conserved properly by the black polythene mulch, which subsequently helped in increasing curd yield per hectare. Hashem (2005) observed the maximum average yield (17.6 t/ha) from black polythene mulch.

Combined effect of different micronutrients and mulching showed statistically significant differences on curd yield per hectare of broccoli (Appendix IX). The highest curd yield per hectare (28.76 ton) was found from T_3M_2 which was followed (27.31 ton and 26.50 ton) by T_3M_1 and T_2M_2, whereas the lowest curd yield per hectare (12.97 ton) from T_0M_0 treatment combination (Table 16).

4.17 Economic analysis

Input costs for land preparation, fertilizer, mulch, fertilizers and manpower required for all the operations from seed sowing to harvesting of broccoli were recorded as per plot and converted into cost/hectare (Appendix X). Price of broccoli was considered as per present market rate basis. The economic analysis presented under the following headings-

4.17.1 Gross return

The combination of different micronutrients and mulching showed different value in terms of gross return under the trial (Table 17). The highest gross return (Tk. 575,200/ha) was obtained from the treatment combination T_3M_2 and the second highest gross return (Tk. 546,200/ha) was found in T_3M_1. The lowest gross return (Tk. 259,400/ha) was obtained from T_0M_0.

4.17.2 Net return

In case of net return, different micronutrients and mulching showed different levels of net return under the present trial (Table 17). The highest net return (Tk. 303,479/ha) was found from the treatment combination T_3M_2 and the second highest net return (Tk. 291,174/ha) was obtained from the combination T_3M_1. The lowest (Tk. 22,093/ha) net return was obtained T_0M_0.

4.17.3 Benefit cost ratio

In the different micronutrients and mulching the highest benefit cost ratio (2.14) was noted from the combination of T_3M_1 and the second highest benefit cost ratio (2.12) was estimated from the combination of T_3M_2. The lowest benefit cost ratio (1.09) was obtained from T_0M_0 (Table 17). From economic point of view, it is apparent from the above results that the combination of T_3M_1 was better than rest of the combination in broccoli cultivation.

Table 17. Cost and return of broccoli cultivation as influenced by different micronutrients and mulching

Treatments	Cost of production (Tk./ha)	Yield of broccoli (t/ha)	Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
T_0M_0	237,308	12.97	259,400	22,093	1.09
T_0M_1	254,003	20.84	416,800	162,798	1.64
T_0M_2	270,698	21.51	430,200	159,503	1.59
T_1M_0	237,708	15.59	311,800	74,092	1.31
T_1M_1	254,403	23.29	465,800	211,397	1.83
T_1M_2	271,098	24.14	482,800	211,702	1.78
T_2M_0	237,975	16.06	321,200	83,225	1.35
T_2M_1	254,670	24.56	491,200	236,530	1.93
T_2M_2	271,365	26.50	530,000	258,635	1.95
T_3M_0	238,331	16.54	330,800	92,469	1.39
T_3M_1	255,026	27.31	546,200	291,174	2.14
T_3M_2	271,721	28.76	575,200	303,479	2.12

Market price of broccoli @ BDT 20,000/ton

T_0: No micronutrients

T_1: $Zn_{4.0}$ kg/ha

T_2: $Zn_{4.0}$ + $B_{1.5}$ kg/ha

T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha

M_0: No mulch

M_1: Water hyacinth mulch

M_2: Black polythene mulch

Chapter 5

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka at the period of October 2015 to February 2016 to find out the effect of different micronutrients and mulching on the growth and yield of broccoli. The seeds of broccoli (*Brassica oleracea var.* italica L.) cv. Green magic were used as planting materials for this experiment. The experiment consisted of two factors: Factor A: Micronutrients (4 levels) as- T_0: No micronutrients, T_1: $Zn_{4.0}$ kg/ha, T_2: $Zn_{4.0}$ + $B_{1.5}$ kg/ha, T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha and Factor B: Mulching materials (3 levels) as- M_0: No mulch (control), M_1: Water hyacinth, M_2: Black polythene. The two factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on yield contributing characters and yield were recorded and significant variation was observed for different treatment.

In case of different micronutrients, at harvest, the tallest plant (67.58 cm) was recorded from T_3, whereas the shortest plant (61.76 cm) from T_0. At harvest, the maximum number of leaves per plant (22.91) was found from T_3, while the minimum number of leaves per plant (21.38) from T_0. At harvest, the longest leaf (43.90 cm) was found from T_3, whereas the shortest leaf (39.48 cm) from T_0. At harvest, the highest leaf breadth (18.75 cm) was found from T_3, while the lowest (17.46 cm) from T_0. The maximum days to 1st curd initiation (60.11) was recorded from T_0, whereas the minimum days (56.11) were observed from T_3. The longest stem (21.97 cm) was recorded from T_3, whereas the shortest stem (19.76 cm) was found from T_0. The highest stem diameter (2.92 cm) was recorded from T_3, whereas the lowest stem diameter (2.29 cm) was found from T_0. The longest root (23.55 cm) was found from T_3, while the shortest root (21.96 cm) was found from T_0. The highest roots fresh weight per plant (31.76 g) was found from T_3, whereas the lowest weight (30.10 g) was found from T_0. The highest primary curd weight (492.05 g) was recorded from T_3, whereas the lowest primary curd weight (396.10 g) was found from T_0. The highest primary curd diameter (9.26 cm) was recorded from T_3, while the lowest primary curd diameter (8.31 cm) was observed from T_0. The maximum number of secondary curd/plant (3.03) was observed from T_3, whereas the minimum number of secondary curd/plant (2.54) was found from T_0. The highest secondary curd weight (75.50 g) was observed from T_3, while the lowest weight (60.91 g) was recorded from T_0. The highest dry matter content of curd (13.80 g) was found from T_3, while the lowest dry matter content of curd (13.10 g) was observed from T_0. The highest curd yield/plot (8.71 kg) was observed from T_3, while the lowest curd yield/plot (6.64 kg) was recorded from T_0. The highest curd yield/hectare (24.20 ton) was recorded from T_3, whereas the lowest curd yield/hectare (18.44 ton) was found from T_0.

For different mulching, at harvest, the tallest plant (68.18 cm) was observed from M_2, while the shortest plant (59.11 cm) from M_0. At harvest, the maximum number of leaves per plant (23.83) was observed from M_2, whereas the minimum number (20.70) from M_0. At harvest, the longest leaf (44.11 cm) was found from M_2, whereas the shortest leaf (40.56 cm) from M_0. At harvest, the highest leaf breadth (19.18 cm) was recorded from M_2, while the lowest leaf breadth (17.01 cm) from M_0. The maximum days from transplanting to 1st curd initiation (59.17) was observed from M_0, while the minimum days from transplanting to 1st curd initiation (55.92) was recorded from M_2. The longest stem (23.09 cm) was observed from M_2, while the shortest stem (18.22 cm) was attained from M_0. The highest stem diameter (2.92 cm) was found from M_2 and the lowest stem diameter (2.35 cm) was observed from M_0. The longest root (25.12 cm) was observed from M_2, whereas the shortest root (20.65 cm) was observed from M_0. The highest roots fresh weight (32.32 g) was recorded from M_2 and the lowest roots fresh weight (29.90 g) was found from M_0. The highest primary curd weight (517.71 g) was observed from M_2, while the lowest primary curd weight (329.16 g) was recorded from M_0. The highest primary curd diameter (9.22 cm) was observed from M_2 and the lowest (8.35 cm) from M_0.

The maximum number of secondary curd/plant (3.09) was found from M_2, while the minimum number (2.35) from M_0. The highest secondary curd weight (76.83 g) was found from M_2, whereas the lowest secondary curd weight (55.00 g) was observed from M_0. The highest dry matter content of curd (13.89 g) was found from M_2 and the lowest dry matter content of curd (13.23 g) from M_0. The highest curd yield/plot (9.08 kg) was found from M_2 and the lowest curd yield/plot (5.51 kg) was observed from M_0. The highest curd yield/hectare (25.23 ton) was found from M_2, while the lowest curd yield/hectare (15.29 ton) was observed from M_0.

Due to combined effect of different micronutrients and mulching, at harvest, the tallest plant (71.04 cm) was found from T_3M_2, whereas the shortest plant (54.61 cm) was observed from T_0M_0. At harvest, the maximum number of leaves per plant (24.40) was found from T_3M_2, whereas the minimum number (19.20) was recorded from T_0M_0 treatment combination. At harvest, the longest leaf (46.79 cm) was recorded from T_3M_2, while the shortest leaf (37.46 cm) was observed from T_0M_0 treatment combination. At harvest, the highest leaf breadth (20.27 cm) was found from T_3M_2, whereas the shortest leaf breadth (16.27 cm) was found from T_0M_0 treatment combination. The maximum days from transplanting to 1st curd initiation (62.00) was found from T_0M_0, while the minimum days from transplanting to 1st curd initiation (50.33) was recorded from T_3M_2 treatment combination. The longest stem (24.92 cm) was recorded from T_3M_2, whereas the shortest stem (17.57 cm) was observed from T_0M_0 treatment combination. The highest stem diameter (3.39 cm) was recorded from T_3M_2, whereas the lowest stem diameter (2.16 cm) was observed from T_0M_0 treatment combination. The longest root (26.49 cm) was observed from T_3M_2, whereas the shortest root (19.48 cm) was observed from T_0M_0 treatment combination. The highest roots fresh weight (33.74 g) was recorded from T_3M_2, whereas the lowest fresh weight (28.56 g) was found from T_0M_0 treatment combination. The highest primary curd weight (569.66 g) was found from T_3M_2, whereas the lowest primary curd weight (281.35 g) was observed from T_0M_0 treatment combination. The highest primary curd diameter (9.68 cm) was recorded from T_3M_2, whereas the lowest primary curd diameter (8.07 cm) was observed from T_0M_0. The maximum number of secondary curd/plant (3.47) was found from T_3M_2, whereas the minimum number (2.17) was observed from T_0M_0. The highest secondary curd weight (84.54 g) was recorded from T_3M_2, while the lowest weight (49.78 g) T_0M_0. The highest dry matter content of curd (14.28 g) was found from T_3M_2, whereas the lowest dry matter content of curd (12.59 g) was found from T_0M_0 treatment combination. The highest curd yield/plot (10.35 kg) was recorded from T_3M_2, whereas the lowest (4.67 kg) was found from T_0M_0. The highest curd yield/hectare (28.76 ton) was found from T_3M_2, whereas the lowest (12.97 ton) from T_0M_0 treatment combination.

The combination of different micronutrients and mulching the highest gross return (Tk. 575,200/ha) was obtained from the treatment combination T_3M_2 and the lowest gross return (Tk. 259,400/ha) was obtained from T_0M_0. The highest net return (Tk. 303,479/ha) was found from the treatment combination T_3M_2 and the lowest (Tk. 22,093/ha) net return was obtained T_0M_0. In the different micronutrients and mulching the highest benefit cost ratio (2.14) was noted from the combination of T_3M_1 and the lowest benefit cost ratio (1.09) from T_0M_0.

Conclusion

Among the combination of different micronutrients and mulching, T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha with black polythene mulch induced superior growth, yield contributing characters and yield of broccoli but T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha with water hyacinth gave the highest economic return. Considering benefit cost result, it may be said that $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$ kg/ha micronutrients in presence of recommended doses of $N_{120}P_{100}K_{150}S_{20}$ kg/ha fertilizer with water hyacinth mulch can be used for commercial broccoli production.

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

Response of other variety to the treatments under study may be investigated in future.

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Appendices

APPENDICES

Appendix I. Characteristics of the soil of experimental field

A. Morphological characteristics of the soil of experimental field

Morphological features	Characteristics
Location	Expeimental 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
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

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

Appendix II. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from October, 2015 to February 2016

Month	Air temperature (^{0}C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
October, 2015	26.5	19.4	81	22
November, 2015	25.8	16.0	78	00
December, 2015	22.4	13.5	74	00
January, 2016	24.5	12.4	68	00
February, 2016	27.1	16.7	67	30

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

Appendix III. Analysis of variance of the data on plant height of broccoli at different days after transplanting (DAT) and harvest as influenced by different levels of micronutrients and mulching

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm) at				
		15 DAT	30 DAT	45 DAT	60 DAT	Harvest
Replication	2	0.783	1.955	0.911	4.063	1.235
Micronutrients (A)	3	25.372**	37.443**	60.989**	85.505**	50.619**
Mulching (B)	2	55.100**	121.389**	212.534**	105.721**	300.005**
Interaction (A×B)	6	3.850*	5.174*	35.924**	36.882**	54.533**
Error	22	1.473	2.288	4.099	9.357	7.736

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix IV. Analysis of variance of the data on number of leaves per plant of broccoli at different days after transplanting (DAT) and harvest as influenced by different levels of micronutrients and mulching

Source of variation	Degrees of freedom	Mean square				
		Number of leaves per plant at				
		15 DAT	30 DAT	45 DAT	60 DAT	Harvest
Replication	2	0.043	0.010	0.463	0.781	0.120
Micronutrients (A)	3	0.630*	0.771*	3.272*	7.702*	4.614*
Mulching (B)	2	4.443**	2.230**	19.803**	49.514**	29.703**
Interaction (A×B)	6	0.544*	0.445*	3.488*	5.180*	3.943*
Error	22	0.178	0.200	0.925	2.020	1.327

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix V. Analysis of variance of the data on leaf length of broccoli at different days after transplanting (DAT) and harvest as influenced by different levels of micronutrients and mulching

Source of variation	Degrees of freedom	Mean square				
		Leaf length (cm) at				
		15 DAT	30 DAT	45 DAT	60 DAT	Harvest
Replication	2	0.163	0.108	0.919	1.186	0.630
Micronutrients (A)	3	1.321*	6.452*	8.386**	55.081**	34.494**
Mulching (B)	2	7.595**	17.732**	28.234**	27.138**	37.795**
Interaction (A×B)	6	0.893*	6.050*	7.520**	5.001*	5.963*
Error	22	0.375	1.753	1.958	2.346	2.302

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VI. Analysis of variance of the data on leaf breadth of broccoli at different days after transplanting (DAT) and harvest as influenced by different levels of micronutrients and mulching

Source of variation	Degrees of freedom	Mean square				
		Leaf breadth (cm) at				
		15 DAT	30 DAT	45 DAT	60 DAT	Harvest
Replication	2	0.060	0.008	0.054	0.034	0.168
Micronutrients (A)	3	0.605**	2.035**	3.992**	5.000**	2.887**
Mulching (B)	2	2.189**	4.087**	10.183**	14.326**	14.226**
Interaction (A×B)	6	0.232*	2.058**	1.914*	1.354**	1.705**
Error	22	0.072	0.362	0.587	0.299	0.481

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VII. Analysis of variance of the data on days to 1st curd initiation, stem length, stem diameter, and roots length and roots fresh weight per plant of broccoli as influenced by different levels of micronutrients and mulching

Source of variation	Degrees of freedom	Mean square				
		Days to 1st curd initiation	Stem length of (cm)	Stem diameter (cm)	Root length of (cm)	Roots fresh weight per plant (g)
Replication	2	0.694	1.020	0.005	0.137	0.052
Micronutrients (A)	3	26.843*	8.943**	0.645**	4.728*	5.414*
Mulching (B)	2	32.028*	72.967**	0.970**	60.329**	17.549**
Interaction (A×B)	6	39.287**	5.140*	0.124*	3.465*	4.927*
Error	22	7.210	1.708	0.040	1.236	1.755

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VIII. Analysis of variance of the data on primary curd diameter and primary curd weight and secondary curd number and weight of broccoli as influenced by different levels of micronutrients and mulching

Source of variation	Degrees of freedom	Mean square			
		Primary curd diameter (cm)	Primary curd weight (g)	Number of secondary curd per plant	Secondary curd weight (g)
Replication	2	0.058	73.030	0.004	2.269
Micronutrients (A)	3	1.453**	14674.431**	0.395**	344.231**
Mulching (B)	2	2.364**	131023.642**	1.845**	1682.864**
Interaction (A×B)	6	0.944*	631.970*	0.039**	9.951*
Error	22	0.217	223.945	0.006	3.982

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix IX. Analysis of variance of the data on dry matter content in plant and curd and yield per plot and hectare of broccoli as influenced by different levels of micronutrients and mulching

Source of variation	Degrees of freedom	Mean square			
		Dry matter content of plant (%)	Dry matter content of curd (%)	Curd yield per plot (kg)	Curd yield per hectare (ton)
Replication	2	0.002	0.030	0.010	0.078
Micronutrients (A)	3	1.297*	0.957*	6.861**	52.939**
Mulching (B)	2	2.626**	1.298**	45.648**	352.225**
Interaction (A×B)	6	1.614*	1.458*	0.355**	2.736**
Error	22	0.374	0.273	0.040	0.312

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix X. Per hectare production cost of broccoli

A. Input cost

Treatments	Labour cost	Ploughing cost	Seed cost	Mulching cost	Manure and fertilizers			Insecticide/ pesticides	Sub total (A)
					Cowdung	NPKS	Zn+B+Mo		
T_0M_0	48,000	25,000	8,000	0	30,000	6,500	0	10,000	127,500
T_0M_1	48,000	25,000	8,000	15,000	30,000	6,500	0	10,000	142,500
T_0M_2	48,000	25,000	8,000	30,000	30,000	6,500	0	10,000	157,500
T_1M_0	48,000	25,000	8,000	0	30,000	6,500	360	10,000	127,860
T_1M_1	48,000	25,000	8,000	15,000	30,000	6,500	360	10,000	142,860
T_1M_2	48,000	25,000	8,000	30,000	30,000	6,500	360	10,000	157,860
T_2M_0	48,000	25,000	8,000	0	30,000	6,500	600	10,000	128,100
T_2M_1	48,000	25,000	8,000	15,000	30,000	6,500	600	10,000	143,100
T_2M_2	48,000	25,000	8,000	30,000	30,000	6,500	600	10,000	158,100
T_3M_0	48,000	25,000	8,000	0	30,000	6,500	920	10,000	128,420
T_3M_1	48,000	25,000	8,000	15,000	30,000	6,500	920	10,000	143,420
T_3M_2	48,000	25,000	8,000	30,000	30,000	6,500	920	10,000	158,420

T_0: No micronutrients

T_1: $Zn_{4.0}$

T_2: $Zn_{4.0} + B_{1.5}$

T_3: $Zn_{4.0} + B_{1.5} + Mo_{1.0}$

M_0: No mulch

M_1: Water hyacinth mulch

M_2: Black polythene mulch

Appendix X. Per hectare production cost of broccoli (Cont'd)

B. Overhead cost (Tk./ha)

Treatments	Cost of lease of land (12% of value of land Tk. 12,00000/year	Miscellaneous cost (Tk. 5% of the input cost	Interest on running capital for 6 months (Tk. 12% of cost/year)	Sub total (Tk) (B)	Total cost of production (Tk./ha) [Input cost (A)+ overhead cost (B)]
T_0M_0	90,000	6,375	13,433	109,808	237,308
T_0M_1	90,000	7,125	14,378	111,503	254,003
T_0M_2	90,000	7,875	15,323	113,198	270,698
T_1M_0	90,000	6,393	13,455	109,848	237,708
T_1M_1	90,000	7,143	14,400	111,543	254,403
T_1M_2	90,000	7,893	15,345	113,238	271,098
T_2M_0	90,000	6,405	13,470	109,875	237,975
T_2M_1	90,000	7,155	14,415	111,570	254,670
T_2M_2	90,000	7,905	15,360	113,265	271,365
T_3M_0	90,000	6,421	13,490	109,911	238,331
T_3M_1	90,000	7,171	14,435	111,606	255,026
T_3M_2	90,000	7,921	15,380	113,301	271,721

T_0: No micronutrients

T_1: $Zn_{4.0}$

T_2: $Zn_{4.0}$ + $B_{1.5}$

T_3: $Zn_{4.0}$ + $B_{1.5}$ + $Mo_{1.0}$

M_0: No mulch

M_1: Water hyacinth mulch

M_2: Black polythene mulch