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Effect of Nutrient Management on Growth, Yield and Yield Components of Selective Vegetable Crops in Calcareous Soils of Bangladesh

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EFFECT OF NUTRIENT MANAGEMENT ON GROWTH, YIELD AND YIELD COMPONENTS OF SELECTIVE VEGETABLE CROPS IN CALCAREOUS SOILS OF BANGLADESH

THESIS SUBMITTED TO THE DEPARTMENT OF CROP SCIENCE AND TECHNOLOGY, UNIVERSITY OF RAJSHAHI

FOR THE DEGREE
OF
DOCTOR OF PHILOSOPHY
IN
CROP SCIENCE AND TECHNOLOGY

BY

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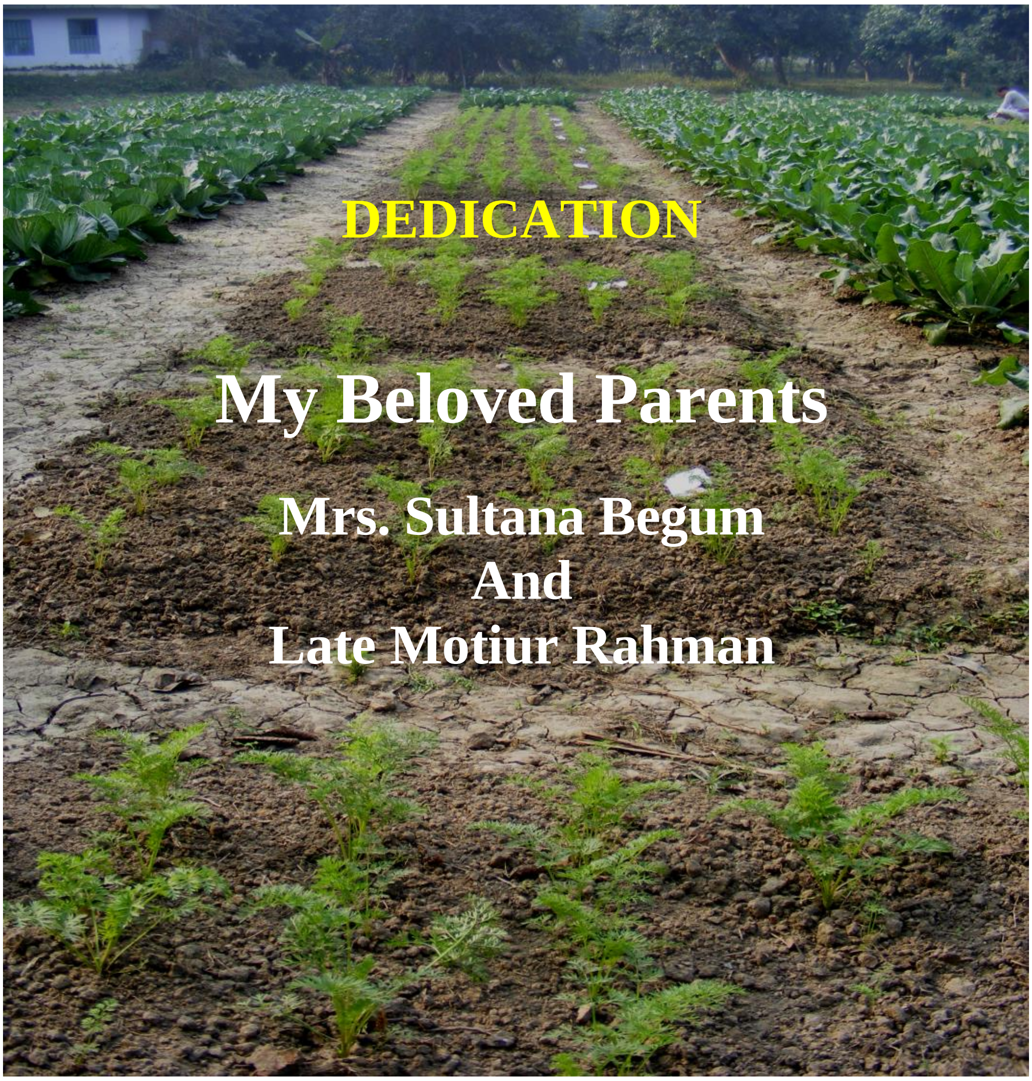
DEDICATION
My Beloved Parents
Mrs. Sultana Begum
And
Late Motiur Rahman

The Author

DECLARATION

I do hereby declare that the thesis entitled "**EFFECT OF NUTRIENT MANAGEMENT ON GROWTH, YIELD AND YIELD COMPONENTS OF SELECTIVE VEGETABLE CROPS IN CALCAREOUS SOILS OF BANGLADESH**" as a partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy (Ph. D) at the Department of Crop Science and Technology, University of Rajshahi, Bangladesh, is exclusively the outcome of my own research work done under the guidance and supervision of Dr. Md. Nurul Alam, Professor, Department of Crop Science and Technology, University of Rajshahi, Rajshahi, Bangladesh. I also declare that this work has not been submitted in full or in part for awarding of any other Degree or Diploma to this or any other University or Institute. I further declare that no part of the thesis is a reproduction from any other source, published or unpublished, without acknowledgement.

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CERTIFICATE

This is to certify that the research fellow **Mst. Noor Akter Naher** is the sole author of the dissertation entitled **“EFFECT OF NUTRIENT MANAGEMENT ON GROWTH, YIELD AND YIELD COMPONENTS OF SELECTIVE VEGETABLE CROPS IN CALCAREOUS SOILS OF BANGLADESH”**. This research work is her own research under my supervision for the award of the degree of **Doctor of Philosophy (Ph.D)** from the Department of Crop Science and Technology, University of Rajshahi, Rajshahi, Bangladesh. So far I know, no other person was associated with the completion of the study or anybody has done a research on the same topic as yet.

I have gone through the draft and final version of the dissertation for submission to the Department of Crop Science and Technology, University of Rajshahi, Rajshahi, Bangladesh as a partial fulfillment of the requirements for the award of the degree “Doctor of Philosophy”.

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The Author

ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro- Ecological Zone
Agric.	=	Agriculture
Agril.	=	Agricultural
BARC	=	Bangladesh Agricultural Research Council
BARI	=	Bangladesh Agricultural Research Institute
BAU	=	Bangladesh Agricultural University
BBS	=	Bangladesh Bureau of Statistics
cm	=	Centimeter
cv.	=	Cultivers
DAE	=	Department of Agriculture
DAS	=	Days After Sowing
DAT	=	Days After Transplanting
DMRT	=	Duncun's Multiple Range Test
FAO	=	Food and Agriculture Organization
Fig.	=	Figure
g	=	gram
ha	=	hectare
J.	=	Journal
LSD	=	Least Significant Difference
ppm	=	Parts Per Million
q	=	Quintal
RCBD	=	Randomised Complete Block Design
Sci.	=	Science
Soc.	=	Society
t/ha	=	Ton per hectare
TSP	=	Triple super phosphate
MP	=	Muriate of potash
MoA	=	Ministry of Agriculture

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ABSTRACT

Six field experiments were conducted to evaluate the effect of nutrient management on growth, yield and yield components of selected vegetable crops (cabbage, cauliflower and carrot) from November 2008 to March 2009 and November 2009 to March 2010 in calcareous soils of Bangladesh, which was originated "High Ganges River Floodplain". There were two experiments in each crop. The treatments of first experiment of cabbage, cauliflower and carrot *viz.* T_0=Control, T_1=N, T_2=NP, T_3=NPK, T_4=NPKS, T_5=NPKZn, T_6=NPKB, T_7=NPKMo, T_8= NPKSZn, T_9=NPKSZnB, T_{10}=NPKSZnBMo with three replications in Randomized Complete Block Design (RCBD) during 2008-2009 season. The dose of N-P-K-S-Zn-B-Mo were 150-50-100-20-3-3-1 Kg/ha, respectively. The treatments of second experiment of cabbage, cauliflower and carrot, namely T_0= Control, T_1 =Zn_2B_2, T_2=$Zn_2B_2Mo_{0.5}$, T_3=$Zn_3B_3Mo_1$, T_4=$Zn_2B_2Mo_{.5}Mn_4$, T_5=$Zn_2B_2Cu_1$ $Mo_{0.5}Mn_4$, T_6= $Zn_3B_3Cu_2Mo_1Mn_8$ (figures in subscrip indicate doses of concern nutrients) with basal dose of N-150, P-50 and K-100 Kg/ha. The experiments were conducted in same field and the initial soil properties were silty clay loam in texture. The organic matter of the experimental field soil was very low, N and S also low. The land was medium fertile and pH 7.2.

Application of different nutrients exhibited significant influence on growth and yield of cabbage. The highest plant spread (70.76 cm), height (37.89 cm), leaf length (37.83cm) and breadth (27.13 cm), number of loose leaves (19.80), head thickness(12.85 cm), head diameter (23.03 cm), marketable head yield (76.53 t/ha), and also early head formation and maturity was obtained from NPKB. The treatment NPK+S shows the highest weight of loose leaves (640 g/plant) and decreased the weight of folded leaves or head weight. Whereas, the treatment NPK+B increased the folded leaves or maximum head weight (1894.18 g/plant). The yield was highly increased (43% over NPK) when NPK+B was added to the soil as the head formation was positively associated with B. In the second experiment of cabbage, the effect of Zn and B on foliage coverage was prominent in all growth periods. It was observed that Zn, B and Mo at 2.0, 2.0 and 0.5 kg/ha dose had the highest effect on head diameter (23.41cm), head thickness (12.41 cm), weight of marketable head (2181.20 g/plant), gross weight (2997.15g/plant) and total yield (88.10 t/ha) of cabbage which increased 43.76% production over control. The results exhibited that higher doses of Zn, B and Mo (3, 3 and 1 kg/ha respectively) reduced the yield (7.62 t/ha) compared with lower doses (2.0, 2.0 and 0.5 kg/ha, respectively). Addition of Cu and Mn showed negative response to head yield of cabbage.

In the first experiment of cauliflower, the treatment NPKSBMo produced the longest (44.63 cm) as well as the widest leaf (22.08 cm). The nutrients S, Zn, B and Mo increased

the leaf breadth, canopy diameter when added individually with NPK fertilizers. Application of boron had significant and positive effect on plant height (44.18 cm). The maximum weight of leaves (710.07 g/plant), largest diameter of curd (16.26 cm) and maximum height of curd (9.73 cm) were recorded from the treatment containing NPKB. NPKS, NPKZn and NPKSZn decreased the weight of leaf, curd diameter and curd height than NPK. The result shows that B had positive and significant effect on weight of leaf, curd diameter and curd height, and Mo had positive and significant effect on weight of leaf but insignificant effect on curd diameter and curd height. The maximum marketable curd weight (715.30 g/plant), curd weight (499.78 g/plant), marketable curd yield (28.9 t/ha) was recorded from NPK+B treatment which increased the yield 437.87% over control and 30.83% over NPK. The treatment NPK+S and NPK+Zn reduced the yield 19.92% and 7.92% over NPK, respectively. When Mo added with NPK the curd yield was increased 391.98% over control and 17.12% over NPK. It is noted that B and Mo have positive effects on curd yield of cauliflower. In the second experiment of cauliflower, the maximum curd Diameter (16.61 cm), thickness (9.95 cm), curd weight (707.8 g/plant), marketable curd weight (886.7 g/plant) and highest yield (35.82 t/ha, 24.67% increased over control) was obtained from treatment $Zn_2B_2Mo_{0.5}$

In the first experiment of carrot, the maximum plant height (51.08 cm) and root length (16.22 cm) was found by the application of NPK. The maximum root diameter (4.66 cm) was recorded when all nutrients (T_{10}) added to the soil. Maximum fresh weight of leaves (95.83 g/plant) was found in NPKSZnBMo. The highest yield (27.48 t/ha) which was 67.48% higher over control was obtained from the plot receiving all the nutrients. In second experiment of carrot, the lower rates of micronutrients produced the maximum plant (60.30 cm). The maximum diameter (6.42 cm) was observed in control plot where NPK as basal. The lower dose of micronutrients ($Zn_2B_2Cu_1Mo_{0.5}Mn_4$) produced the maximum root weight (147.3 g/plant), shoot weight (84.67 g/plant) and root yield (29.76 t/ha) which increased 37.26% root yield over control.

Therefore, it can be concluded that application of B with NPK increased the vigorous vegetative growth and yield of cabbage, and cauliflower. Boron was found more effective in leaf folding or head formation, early head maturity of cabbage and proper curd formation of cauliflower. It is also noted that Mo has positive effect on curd yield of cauliflower. Zinc and Boron alone or combine with NPK shows better performance on carrot yield. Among micronutrients B is required for cabbage, B and Mo for cauliflower, and Zn and B for carrot cultivation in calcareous soils of Bangladesh.

General Introduction

Vegetables are usually considered as high-value crops. The potentiality of vegetables is immense, although it has never been exploited fully. The popularity and demand has been increased during last decade. The area of cultivated horticultural crop is 969.6 thousand hectare which is 11.49% of total cultivable land (8.440 thousand ha). Vegetables including potato are cultivated in 6.25% of the total cultivable land (MoA, 2013). However, there is no significant increase in yield per unit area compared with its potentiality. Improper production practices such as use of imbalance fertilizers and suboptimal irrigation adopted by the growers are the major reasons for such poor yield (Naher *et al*., 2007).

Incremental use of imbalanced fertilizer, less or no use of organic manures, and no use of micronutrients with intensification in cropping have resulted the depletion of soil fertility in Bangladesh. Consequently, micronutrients status has been decreasing day by day and finally soil fertility status of Bangladesh is alarming (Alam, 2006). Identification and management of nutrient deficiency in soils are pre-requisites for sustainable development of crop yield.

Macro and micronutrients are essential for plant growth and proper development. Nitrogen imparts vigorus vegetative growth and dark green colour to plants (Das, 2011). Phosphorus stimulates early root development and growth and helps to establish seedlings quickly and gives rapid and vigorus start to plants, strengthens straw and decreases lodging tendency (Das, 2011). Phosphorus increased vegetative growth and fruit yields (Topcuglu and Yalcin, 1994). Potassium helps in formation of proteins and chlorophyll. It helps in the root development and increase the efficiency of leaf in the manufacture of sugar and starch and it is essential for the translocation of sugar (Das, 2011). Potassium is important in grain formation and is absolutely necessary for tuber development (Brady, 1995). Sulphur increases root growth and stimulate seed formation. It is required for the synthesis of the sulphur-containing amino acids cystine, cysteine and methionine (Das. 2011).

Micronutrients are equally important like major nutrients such as NPK. The only difference is the plants need relatively small quantities of micronutrients. They naturally occur in plants and soils in much lower concentrations. Plants which are grown in micronutrients-deficient soils exhibit similar reduction in productivity as they suffer for macronutrient. Zinc influences the formation of some growth hormones in the plant and also helpful in reproduction of certain plants. Boron helps in the absorption of nitrogen and required for the development of new cells in meristematic tissue (Das. 2011). Requirement of B for plant growth and yield is greater when calcium (Ca) availability is high (Tisdale *et al*. 1995). Boron (B) requirements are common on upland crops in humid regions and also in calcareous soil. Deficiencies of B are widespread in humid regions by leaching losses (Troeh and Thompson, 1993).

There are 30 AEZs, 88 sub-zones and 535 agro-ecological units in Bangladesh (Bhuiya *et al.,* 2005). According to the fertility status of soils in different AEZs, the experimented area belongs to High Ganges River Floodplain soils (AEZ-11) which is one of the most important calcareous soils of Bangladesh containing large amount of $CaCO_3$ as well as high concentration of available Ca^{2+}. The pH generally ranges from 7.0 to 8.5, but in most of the upland soils ranges between 8.0-8.5 (Alam *et al.,* 2010).

In calcareous soils of Bangladesh few researchers worked on cabbage, cauliflower, radish, carrot, onion, garlic, and broccoli. Ahmmad, (2009) reported that Zn+B combination is suitable for cabbage but Zn+B+Mo+Mn combination is suitable for cauliflower for maximum yield in calcarious soils of Bangladesh. Other researchers observed more or less similar results viz. Alam *et al.* (2010) in onion, Alam *et al.* (2009) in cabbage, Alam (2007) in cabbage, Alam (2006) in broccoli, cabbage, cauliflower and onion crops. The deficiencies of Zn and B are more common than other micronutrients in calcareous soils of Bangladesh.

Now-a-days, gradual deficiency of micronutrient is an alarming problem in Bangladesh for all crops. The required quantity of a micronutrient for different crop varies. But constant attention should be given to micronutrient levels and needs. A crop can suffer from nutrient deficiency without showing a specific symptom. If the symptom is evident, the crop is already suffering a deficiency and a yield reduction will result. It would be an economic safeguard to check-and-avoid or, at least, check-and-remedy any yield-robbing problem. Specific vegetable needs special types of micronutrient such as some vegetables are boron loving while some are zinc loving. Normally Zn and B become less available to plants when soil pH increasing. Kevorkov (1972) observed that the effectiveness of minor elements was greater in the unlimed soil and the highest carrot yield was found in B + Mo treated plot.

Inorganic fertilizers today hold the key to the increase of the crop production system of agriculture, being contributed 50% of the total production (BARC, 2005). The inorganic fertilizer supplies sufficient available nutrients readily for proper growth and development of plant. The organic matter also an important source of plant nutrients but contains relatively small amount, which are not readily available. On the other hand, inorganic fertilizer contains specific, higher and readily available plant nutrients. Farmers are applying huge amount of chemical fertilizer mainly nitrogen, phosphorus and potassium rather than applying any micronutrient fertilizer such as B, Mo containing fertilizer to get maximum yield of vegetable.

If a crop fall short of a micronutrient, it cannot give a bumper harvest even with a truckload of NPK. For top yields, all nutrients should be at an optimum level (not deficient, not excess). Micronutrient can play a vital role for maximizing crop production in minimum production cost. Rasp (1985) mentioned that the effect of added trace elements in 12 years of crop rotation in which potatoes and cereals were grown in alternate years and reported that the requirements of B in vegetables are generally more than other corps. In calcareous soils of Bangladesh, Alam (2004) intensively observed that B at 2 kg/ha with NPKS increased cabbage head yield by 119% than NPKS alone.

In fact, information regarding micronutrient requirements for vegetable is scanty in calcareous soils of Bangladesh.

Realizing the essentiality, a study was undertaken to find out the effect of nutrient management on growth, yield and yield components of selective vegetable crops in calcareous soils of Bangladesh with the following objectives:

i. To evaluate the effect of N, P, K, S, Zn, B, Mn, Cu & Mo on growth and yield of selected vegetables (cabbage, cauliflower and carrot); and

ii. To compare the response of micronutrient with macronutrient on growth and productivity of cabbage, cauliflower and carrot.

Chapter 1: Cabbage

Experiment 1

EFFECT OF NUTRIENT MANAGEMENT ON GROWTH, YIELD AND YIELD COMPONENTS OF CABBAGE IN CALCAREOUS SOILS OF BANGLADESH

Experiment 2

EFFECT OF MICRONUTRIENT MANAGEMENT ON GROWTH, YIELD AND YIELD COMPONENTS OF CABBAGE IN CALCAREOUS SOILS OF BANGLADESH

Introduction

Cabbage *(Brassica oleracea* var. *capital* L), belongs to the family Cruciferae, is one of the most important, high nutritive and palatable leafy vegetable in Bangladesh which grown during winter season. It is very popular in tropical, subtropical and temperate regions of the world. It has wide adoption, economic potential and consumer's demand. It is a rich source of protein, minerals and vitamin A (Uddin *et al*., 2009). It has some medicinal value as it prevents constipation, increases appetite, speeds up digestion and is very useful for diabetic patient. The crop was originated from the Western Europe and North shores of the Mediterranean Sea (Chauhan, 1986).

The world production of cabbage is 69,214,270 tons. China is producing 36,335,000 tons, India 5,283,200 tons, Russia 4,054,000 tons, South Korea 3,000,000 tons, Japan 2,390,000 tons etc. (FAO, 2009) and Bangladesh 211,097 tons from 16,102 hectares of land (BBS, 2009). Well drain, fertile, sandy loam or loamy soil having enough organic matter is most ideal for cabbage cultivation. Although it can be grown in hot and humid climate, it is grown best in a cool and moist climate. The optimum temperature for its vegetative growth is 15-22^{0}C. Young plant can tolerate high temperature than mature plant (Uddin *et al*., 2009).

Cabbage is well known to be high nutrient absorption capacity. The supply of proper nutrient must be ensured during its production, which is related to the judicious application of fertilizer. In the upland field, cabbage yields were high when chemical fertilizers were applied (Kamiyama *et al.*, 1995). The crop production system with high yield targets cannot be sustainable unless nutrient inputs to soil are at least balanced against nutrient removal by crops (Jahiruddin and Rijpma, 2004).

Nutrient deficiencies in Bangladesh soils are increasing day by day. One of the major reasons is farmer does not use balanced fertilizer and the nutrient balance in the soils is negative. Farmers of Bangladesh use only about 172 kg nutrients/ha annually (132 kg N, 17 kg P, 17 kg K, 4 kg S and 2 kg Zn+ B+ others), while the crop removal about 250kg/ha (Islam, 2002). As a result other nutrients such as Zn, B, Mo, Mn etc. are being observed as deficient in many parts of Bangladesh.

Some researchers conducted experiments in combination with macro and micro nutrients for cabbage cultivation and recommended few findings such as organic manure (cowdung or poultry manure) with macro and micro-nutrients added to the soil can increase the head yield of cabbage (Farid *et al*., 1998). Boron is a very sensitive micronutrient and the range of deficiency and toxicity are narrow. However, in cole crops like cabbage, boron requirement is very high (Tisdale *et al*., 1995). Ullah *et al*. (1999) reported the significant influence of combined application of N, P, K and S on the yield of cabbage. Akter *et al*. (1999) also observed that the optimum level of NPKSZn and cowdung produced the maximum head yields of Chinese cabbage in Grey Terrace soils of Bangladesh.

The average yield of cabbage is very low in Bangladesh compared to other developed countries due to lack of improved technology, improper use of nutrient, no consideration of demand and contain of micronutrients in the soil by the growers in the country (Islam *et al*., 1989). Therefore, it is necessary to determine the effect of Zn, B, S, Mo as well as major fertilizers for good harvest of cabbage. The present study was undertaken to evaluate some major and minor fertilizers on growth and yield of cabbage in Calcareous soil of Bangladesh with the following objectives:

i. To evaluate the effect of major nutrients such as N, P, K, S and minor nutrients such as Zn, B, Cu, Mn and Mo on the growth and yield of cabbage:
ii. To compare the effect of micronutrients with macronutrients on the growth and yield of cabbage; and
iii. To find out the optimum doses of fertilizers for maximizing yield potentiality of cabbage.

Review of Literature

Cabbage is an important vegetable crop which received much attention to the researchers throughout the world to develop its production techniques. Many research works have been carried out related to fertilizer management in cabbage in different countries including Bangladesh. However, few studies have been carried out on the effects of different macro and micro nutrient elements. A brief review of research works in relation to the effect of some macro and micro nutrients on growth, yield and quality of cabbage are presented in this chapter.

1.2.1 Effect of Nitrogen

Shchelkunova (1974) reported that raising the Nitrogen rate to 280 kg/ha increased the yield of cabbage by 51 t/ha although it slightly raised the production costs. He also found that half of this rate of Nitrogen (140 kg/ha) produced 48.6 t/ha cabbages at the lowest production cost.

Hill (1990) made a trial with 6 levels of Nitrogen viz. 0, 50, 100, 200, 300 and 400 kg/ha indicating 200 kg/ha. He concluded nitrogen to be the best for getting the highest (126.6 t/ha) yield of cabbage. He also noted that the highest rate beyond 200 kg/ha caused soft rot disease, which contributed to the reduction in yield.

Mallik and Bhattacharya (1996) observed that cabbage yield increased with increasing rate of Nitrogen (5.77 and 33.14 t/ha with 0 and 120 kg respectively). Maximum net profit and cost benefit ratio was obtained at 120 kg Nitrogen/ha.

1.2.2 Effect of Nitrogen and Phosphorus

Singh and Nailk (1988) studied the effects of Nitrogen and P_20_5 in 3 spacing on the yield of cabbage cv. Pride. They reported that the closest spacing (45cm×30cm) gave higher numbers of marketable heads with the highest yield. The head weight was the highest at 60×45cm spacing. Nitrogen at 120kg/ha increased yield and number of marketable heads. Application of Phosphate at 60 kg/ha gave the highest yield, average head weight and number of heads.

1.2.3 Effect of Nitrogen, Phosphorus and Potassium

The highest yield (76.60 t/ha) of cabbage was found from the combined effect of 180 kg/ha Nitrogen, 60 kg/ha Phosphorus, 180 kg/ha Potassium and 5 t/ha cowdung (**Anonymous, 1990).** It was reported that a combination of organic and inorganic fertilizer was better than a single fertilizer for cabbage production. Fertilizers at the rate of 240 kg Nitrogen, 60 kg Phosphorus and 120kg Potassium along with cowdung 5 t/ha gave the highest head yield (75 t/ha) of cabbage (var. Atlas-70) at Gazipur condition (**Anonymous, 1991).**

Saxena *et al*. (1993) observed that application of 75 kg Nitrogen, 80 kg P_20_5 and 150 kg K_20/ha gave the highest yield (17.42 t/ha in the first year and 12.03 t/ha in the second year) and was the most economic dose.

Halim *et al*. (1994) carried out an experiment on the effect of different doses of NPK on the growth and yield of cabbage (cv. K-K cross) at Jamalpur, Bangladesh. Nitrogen was applied at 0, 100, 150 and 200 Kg, Phosphorus at 0, 50, 100 and 150 Kg and Potassium at 0, 75, 150 and 225 Kg/ha. Gross yield and marketable head was the maximum with 150 Kg N + 100 Kg P_20_5 + 150 Kg K_20 and 200 Kg N + 100 Kg P_20_5 + 150 Kg K_20 combination respectively. **Kamiyama *et al*. (1995)** obtained maximum cabbage yield in the upland fields when chemical fertilizers were applied with FYM.

U11ah *et al*. (1999) studied the potentiality of cabbage yield at Barisal. Application of 60, 120, 180, 240 Kg Nitrogen/ha increased yield by 58, 70, 73 and 74% over control, respectively. The application of 30, 60, 90 and 120 Kg P_20_5/ha increased head yield by 3, 7, 13 and 9% over control respectively. Application of 50, 100 and 150 Kg K_20/ha increased 5, 9 and 9% and S of 20 and 40 Kg/ha increased yield by 9 and 4% over control respectively. The statistically similar yield was found by the application of 120, 180 and 240 Kg of Nitrogen.

Khan *et al.* (2002) evaluated the influence of Nitrogen, Phosphorus & Potassium on the growth and marketable yield of cabbage. All three nutrients were given in five different combinations with or without FYM. Results showed that N, P_20_5 and K_20 at 160:90:60 kg/ha alone with FYM at 15-20 t/ha gave the maximum total yield. The treatment combination of 60cm × 45cm spacing with organic and inorganic fertilizers gave the highest marketable yield (86.68 t/ha) of cabbage as studied by **Sarker *et al*., (2002).**

1.2.4 Effect of Boron

The application of gypsum to Boron-rich acidic soil reduced Boron toxicity due to formation of calcium-borate complex and also due to increased soil permeability owning to leaching loss of Boron **(Bajwa and Sharma, 1990).**

Tandon (1995) reported the antagonistic relationship between Boron-Calcium, Boron-Magnesium and Boron-Manganese, whereas Boron-Sulphur interaction was both synergistic and antagonistic. He also reported that no deficiency or toxicity symptoms were observed at Calcium/Boron ratio of 365-1578. On the other hand, organic matter application on Boron deficient soils along with Boron increases its retention by forming complexes.

A study on the response to foliar application of micronutrients on yield and quality of cabbage cv. Green Express was carried out by **Sarma *et al*. (2002).** Application of 0.5% borax recorded the highest yield (43.47 t/ha) and harvest index of cabbage (69.01%). The highest quantity of protein (1.36 g/100g) and ascorbic acid (40.46 mg/100g) content were found by spraying o.5% borax and 0.5% ammonium molybdate, respectively. However, foliar application of 0.5% manganese sulfate recorded the highest chlorophyll (0.61 mg/g) content of head.

Alam (2007) studied the effect of eight levels (0, 1, 2, 3, 4, 5, 6, 7 kg/ha) of Boron as boric acid on growth and yield of cabbage in calcareous soils of Bangladesh. The head weight and growth and yield contributing parameters of cabbage increased up to 4.0 kg /ha and after that it decreased gradually with the increase of Boron level. The highest head weight (811.33g) was obtained at 4 kg/ha followed by 3 kg/ha (748.67g) although they were statistically similar. The maximum yield was increased 116.82% in 4 kg/ha and 94.97% by 3 kg/ha. The result suggested that 3-4 kg Boron/ha is suitable for cabbage production in calcareous soils while above 4.0 kg/ha may be harmful.

1.2.5 Effect of different nutrients

Yamada and Kamata (1989) studied the effect of composted cattle manure, rapeseed meal and mineral fertilizer on vegetables and soil fertility. They described that cabbage yield was higher with mineral fertilizer than other treatments. However, cabbage yields on the mineral fertilizer plot decreased without the application of agricultural chemicals, whereas yields on cattle manure and rapeseed meal plots were not affected.

At Gazipur conditions, **Farid *et al*. (1998)** studied the efficiency of poultry manure and cowdung alone and in combination with mineral fertilizers on the yield of cabbage (var. Atlas-70). They reported that the head yield was increased both by cowdung and poultry manure with macro and micro-nutrients added to the treatments. The effect of mineral fertilizers and mixture of organic and mineral fertilizers were evaluated on cabbage yield by **Quattrucci and Canali (1998)**. They observed that mixture of organic and mineral fertilizers gave the highest total and marketable yields.

Akter *et al.* (1999) tested different rates of NPKSZn and cowdung on cabbage. The treatment N- 200 Kg, P_20_5 -90 Kg, K_2O-100 Kg, S-20 Kg, Zn -5 Kg and cowdung 5 t/ha produced the highest head yield 67.18 t/ha. They suggested that Phosphorus efficiency reached its peak only at 90 Kg/ha and further addition not only decreased the yield but also reduced diameter of head. Potassium addition up to 100 Kg/ha also influenced the yield progressively and significantly. The application of 20 and 40 kg S/ha produced statistically similar head yield and head diameter. Addition of Zn 5 Kg/ha significantly increased head yield.

Azad (2000) reported that the maximum plant height, plant spread number of total loose and fresh leaves, diameter and thickness of head, length and diameter or stem, number of roots, fresh and dry weight of roots, gross and marketable yield of cabbage were obtained when organic manures and inorganic fertilizers were used in combination.

Sarker *et al.* (2003) studied the effect of different sources of nutrients and mulching on the growth and yield of cabbage. The treatment combination of organic and inorganic fertilizers produced the highest (79.01 t/ha) marketable yield. The treatment combination of organic and inorganic fertilizers with black polythene sheet mulch gave the highest marketable yield (97.83 t/ha). Increasing trend of plant heights were found up to organic + inorganic fertilizers at 30 and 60 DAT and inorganic fertilizer treatment at 90 DAT during the growth period. The maximum plant spread (71.41cm) and number of loose leaves (18.06cm) was obtained with organic and inorganic fertilizer at 90 DAT. Similarly, the treatment organic and inorganic fertilizer produced the maximum head diameter (24.83cm), head thickness (14.55cm) and head weight (2.56 kg).

The effect of some micronutrients such as boron, manganese, iron, copper, molybdenum and zinc on the growth and yield of cabbage var. 'Golden Acre' was investigated by **Kanujia *et al.* (2006)**. The study revealed that the foliar application of Zn at the rate of 100 ppm gave maximum plant height during both the seasons, whereas the maximum yield was recorded with foliar application of mixture of all nutrients at the rate of 100 ppm during both the seasons.

Materials and Methods

Two experiments were conducted to investigate the effect of nutrient management on cabbage yield in calcareous soils of Bangladesh. First experiment was done from November 2008 to March 2009 and second experiment was done from November 2009 to March 2010. This chapter describes the materials and methods of these experiments which include a short description of experimental site and soil, climate, planting materials, layout of treatments, manure and fertilizations, intercultural operations, weed and pest management, data collection, harvesting and statistical analysis.

1.3.1 Experimental Site and Soil

The present investigation was conducted at the Horticulture Centre, DAE, Kallyanpur, Chapai Nawabganj. The soil of the experimental site was silty clay loam and belongs to the High Ganges River Floodplain, AEZ-11 (BARC, 2005). The location map is shown in appendix 1. The soil sample (0-15cm) was collected and analyzed of soil texture by Hydrometer method and other parameters by Hunter (1984) from SRDI (Soil Resources Development Institute), Regional Lab, Shaympur, Rajshahi. The physico-chemical properties of the soil of the experimental plots are presented in Appendix 2.

1.3.2 Climate

The experimental area was under the sub-tropical in nature, which is characterized by three distinct seasons, the monsoon extending from May to October, the winter or dry season from November to February and pre-monsoon period or hot season from March to April. The seasonal condition comprises of sufficient precipitation during the months from April to September and scant or no rainfall during the rest of the months of the year. Plenty of sunshine and moderately low temperature prevails during Rabi season from October to March which is suitable for growing Rabi vegetables in Bangladesh.

Details of the weather data such as temperature, rainfall, and relative humidity during the period of the experiment were collected from the Regional Horticulture Research Station, Chapai Nawabgonj and have been presented in Appendix 3a and 3b.

1.3.3 Treatments of Experiment

A total of 11 treatments including the untreated control were selected in experiment 1 while in experiment 2 include only 7 treatments. The experimental treatments were as follow:

Experiment 1

T_o = Control
T_1 = N
T_2 = NP
T_3 = NPK
T_4 = NPKS
T_5 = NPKZn
T_6 = NPKB
T_7 = NPKMo
T_8 = NPKSZn
T_9 = NPKSZnB
T_{10}= NPKSZnBMo

Experiment 2

T_0 = Control
T_1 = Zn_2B_2
T_2 = $Zn_2B_2Mo_{0.5}$
T_3 = $Zn_3B_3Mo_1$
T_4 = $Zn_2B_2Mo_{.5}Mn_4$
T_5 = $Zn_2B_2Cu_1Mo_{0.5}Mn_4$
T_6 = $Zn_3B_3Cu_2Mo_1Mn_8$

NB: 0.5, 1, 2, 3, 4 and 8 indicated Kg per hectare, where N_{150}, P_{50}, K_{100} were applied as basal dose.

1.3.4 Land preparation

The selected land was opened on 3 November, 2008 for the first experiment and on 7 November 2009 for the second experiment with a power tiller and it was exposed to the sun for 7 days prior to next ploughing. It was prepared afterwards by ploughing and cross ploughing followed by laddering. Large clods were broken into pieces by hand tools, and weeds and stubbles were removed from the field. Finally, the land was leveled and the soil was taken into good tilth.

1.3.5 Design and layout of the experiment

The layout of the experiments was Randomized Complete Block Design (RCBD) with three replications. Each block was consisted of 11 unit plots in experiment 1 and 7 unit plots in experiment 2. The size of each unit plot was 3.3 m × 2.25 m. The gap between the plots was 50cm and between the blocks was 100 cm. The field layout was done on 12 November, 2008 for the first experiment and on 15 November 2009 for the second experiment.

1.3.6 Planting materials

The seedling of cabbage cv. Atlas-70 was used in the experiments. The seedlings were collected from Horticulture Centre, DAE, Kallyanpur, Chapai Nawabganj.

1.3.7 Doses, sources of nutrients and methods of application

The doses and sources of the fertilizers were applied into the experiment 1 and 2 were as follow:

Table 1.3.1 Dose of different nutrients applied to the experiment 1.

Name of nutrient elements	Dose (kg/ha)	Source of Nutrient	% Nutrient
N	150	Urea = $CO(NH_2)_2$	N = 46
P	50	TSP = $Ca(H_2PO_4)_2$	P = 21
K	100	MOP = KCl	K = 50
S	20	Gypsum = $CaSO_4.2H_2O$	S = 18
Zn	3	Zinc oxide = ZnO	Zn = 78
B	3	Boric acid = H_3BO_3	B = 17
Mo	1	Ammonium molybdate = $(NH_4)_6MO_7O_{24}.2H_2O$	Mo = 54

Table 1.3.2 Dose of different nutrients applied to the experiment 2.

Treatment	Dose (kg/ha)				
	Zn	B	Mo	Cu	Mn
T_0 = Control	-	-	-	-	-
$T_1 = Zn_2B_2$	2	2	-	-	-
$T_2 = Zn_2B_2Mo_{0.5}$	2	2	0.5	-	-
$T_3 = Zn_3B_3Mo_1$	3	3	1	-	-
$T_4 = Zn_2B_2Mo_{.5}Mn_4$	2	2	0.5	-	4
$T_5 = Zn_2B_2Cu_1Mo_{0.5}Mn_4$	2	2	0.5	1	4
$T_6 = Zn_3B_3Cu_2Mo_1Mn_8$	3	3	1	2	8

As basal dose 150 kg N, 50 kg P_2O_5 and 100 kg K_2O were applied in experiment 2. The source of Mn was Manganese di-oxide and Cu from cupper sulphate. The whole amount of TSP, gypsum, zinc oxide, boric acid, ammonium molybdate, maganese di-oxide, cupper sulphate and 50% of urea and MOP were applied during final plot preparation. Rest MP and urea were applied in two equal installments at 15 and 35 days after planting of seedlings followed by irrigation.

1.3.8 Transplantation of seedling

Cabbage seedlings of 30 days were transplanted in the experimental field on 15 November 2008 in the first experiment and on 17 November 2009 in the second experiment, maintaining a spacing of 55 cm × 45 cm. To avoid damage of the roots, seedbeds were watered in the morning before uprooting the seedlings and transplanted in the afternoon of the same day. After transplanting, seedlings were lightly watered. The young transplanted seedlings were kept under pieces of banana leaf sheath during the day time to protect their scorching by sunshine and opened at night to allow them receiving dew. Shading and watering were continued for 3 days until the seedlings were established.

1.3.9 Intercultural operations

1.3.9.1 Weeding and mulching

Weeds were removed three times to keep the plots free from weeds and the soil was mulched by breaking the upper crust for easy aeration and to conserve soil moisture as and when needed.

1.3.9.2 Irrigation

Irrigation water was provided at 15, 35 and 55 days after planting of seedlings by observing the soil moisture condition. However, each top-dressing was followed by irrigation. The irrigation was done carefully of each unit plots.

1.3.9.3 Gap filling

The experimental plots were regularly observed to find out any damage and dead seedlings for replacement. Gap filling was done as and when required with the border plants.

1.3.9.4 Plant protection

Malathion 57 EC @ 2ml/L was sprayed once to control the cutworm insects.

1.3.10 Harvest of crops

Cabbage was harvested plot wise at different date after attaining maturity. The crop was harvested from 11 February to 02 March 2009 from the first experiment and from 14 February to 05 March 2010 from the second experiment. Before harvesting, head compactness of the cabbage was tested by pressing with thumb. The compact or matured head showed comparatively hard feelings. Ten sample plants were harvested at first from each plot and then the whole plot was harvested.

1.3.11 Mathods of data Collection

To assess the effect of nutrient management on growth, yield and yield components of cabbage in calcareous soils of Bangladesh, data on the following parameters were recorded from the sample plants during the course of experiment. The sampling was done randomly in each plot in such a way that the border effect could be avoided. For this the outer two lines and the outer plants of the middle lines were excluded. Data were recorded at 30, 45, 60, 75, and at harvest.

1.3.11.1 Height of plant

The height of the sample plants was measured on the basis of average height of 10 plants from the ground level to the tip of the highest leaves and expressed in centimeter.

1.3.11.2 Spread of plant

Land area covered by the plant was estimated by putting a meter scale on the canopy and was expressed in centimeter.

1.3.11.3 Number of leaves or loose leaves

The total number of leaves or loose leaves per plant was counted from 10 selected plants of each plot and mean value was recorded.

1.3.11.4 Length and breadth of largest leaf

Length of the largest leaf per plant was measured in cm with a meter scale from the base of the petiole to the tip. Breadth of the largest leaf also measured with the same scale.

1.3.11.5 Fresh weight of root, stem, leaves and head

The fresh weight of root, stem, leaves and head were taken in gram by weighing with an electrical balance.

1.3.11.6 Length/thickness and diameter of head

The heads from sample plants were sectioned vertically at the middle position with a sharp knife. The diameter of the head was measured in centimeter with a meter scale as the horizontal distance from one side to other side of the widest part of the sectioned head and mean value was recorded. The thickness of head was measured in centimeter with a meter scale as the vertical distance from the lower to the upper most leaves of head after sectioning it vertically at the middle position and mean value was found out.

1.3.11.7 Days required for head formation

Days were counted from the date of transplanting to the start of head formation in selected sample plants and mean value for a unit plot was recorded.

1.3.11.8 Days required for head maturity

Days required for head maturity was counted from the date of transplanting to that of attainting head maturity for selected sample plants and mean value for a unit plot was recorded.

1.3.11.9 Fresh weight of loose leaves at harvest

The fresh weight of loose leaves was taken at the harvest time and expressed in gram and mean value for a unit plot was recorded.

1.3.11.10 Dry matter in leaves and heads

Sample of two hundred gram (g) chopped leaves/head from sample plants was dried in the direct sun for two days and then it was dried in an oven at 70°C for three days till the weight was constant. The dry weight was recorded in gram (g) and mean value was calculated. Percent dry matter was calculated by using the following formula:

$$\text{Dry matter (\%)} = \frac{\text{Dry weight of loose leaves/heads}}{\text{Fresh weight of loose leaves/heads}} \times 100$$

1.3.11.11 Gross and head yield

The yield in kilogram (kg) per plot was converted into yield per hectare and was expressed in metric ton (t).

1.3.12 Statistical analysis

The collected data on different parameters were analyzed statistically using MSTAT C Statistical package programme. The means for all the treatments were calculated and analyses of variances of all the characters studied were performed by F-test. The significance of the differences among the means was evaluated by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Results and Discussion

Two experiments were carried out to investigate the effect of nutrient management on growth and yield of cabbage. The findings of the experiments are presented under separate heads.

Experiment 1

Effect of nutrient management on growth, yield and yield components of cabbage in calcareous soils of Bangladesh

1.4.1.1 Plant spread

A good plant spread indicates good growth, development and productivity of the plants. The present study indicated significant influenced on the spread of cabbage plant by different fertilizers at different growth period (Fig. 1.4.1 and Appendix 4). The spread was rapidly increased up to 60 days, and then increased gradually up to 75 days while after 75 days, the spread was gradually decreased.

At 30 DAT, the spread was markedly influenced due to the addition of different fertilizers to the soil. The spread was more prominent when B was added to the soil. It was varied from 28.73 to 45.64 cm. The largest spread (45.64 cm) was obtained in T_6 (NPK+B) followed by T_{10} (NPK+SZnBMo). The treatment $T_{3,}$ T_5, T_8 and T_9 were statistically similar.

At 45 DAT, the spread varied widely from 33.57 to 54.43cm. The largest spread (54.43cm) was obtained from T_6 (NPK+B). Application of N, K and B significantly increased plant spread while S and Zn had negative effect. The treatments T_3 and T_8 were statistically similar.

The results showed that the added B (T_6) was more effective as B can be fixed with organic matter at primary stage. The results are in agreement with the findings of Das (1999) who reported that added Ca and Mg can fix available B. Application of N P, K, S & Zn significantly increased plant spread.

At 60 DAT, the spread ranged from 39.57-65.33cm. The highest spread (65.33cm) was obtained in T_6 followed by T_{10}. The addition of N, P, K and B significantly increased spread of the plant while S and Zn had negative response in this stage. The lowest spread was found in control.

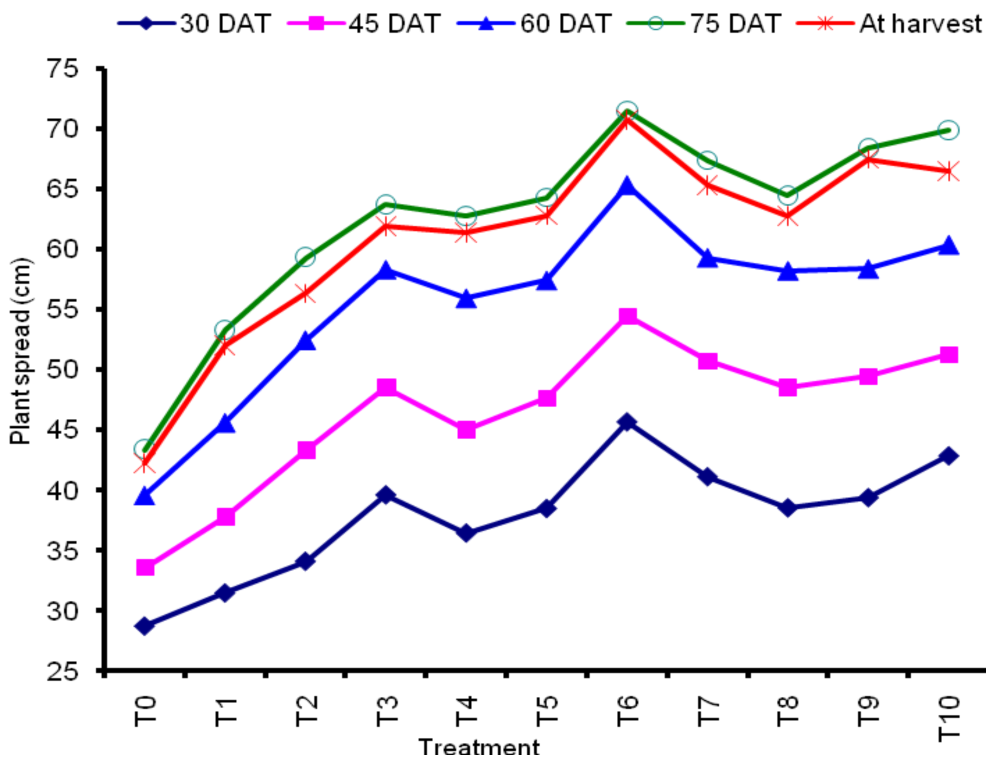

Figure. 1.4.1 : The spread of cabbage plant as influenced by different nutrient combinations.

At 75 DAT, the maximum spread was observed than previous growth period. The highest spread (71.45 cm) was obtained from T_6. The effect of B was more prominent in first half of growth period. It may be concluded that with few exceptions S and Zn decreased the plant spread as they decrease B availability in the soil and B can fix with organic matter during early stage of crop growth. The results are in agreement with the observation of Tandon (1995) and Das (1999).

At harvest, the highest coverage (70.76 cm) was recorded in T_6 (NPK +B) as noted in all the growth stages monitored. The results indicated that boron had significant effect on the spread of cabbage plant while sulphur showed no response when added with NPK.

The results are inpartial with the findings of Firoz *et al.* (2008) and Sarma *et al.* (2002). However, there was no statistical difference between treatments T_3, T_4 and T_8; T_9 and T_{10}. During harvest reduced plant spread was noted although the rate was slow comparing with the increasing rate of previous growth period.

1.4.1.2 Plant height

The height of the plant was significantly influenced by different nutrient combination and increased gradually up to 75 DAT in respect of all treatments at different growth periods (Fig.1.4.2 and Appendix 5).

At 30 DAT, the plant height was varied from 23.53 to 32.42 cm. The tallest plant was recorded in the treatment T_6 followed by T_7, T_{10}, and T_3 while the shortest was measured in the control plots. All the plants increased differently due to different treatments as monitored after 45 days. It varied from 24.70 to 35.13 cm. The tallest plant was recorded in treatment T_6 followed by T_3, T_7, and T_{10} while the shortest was observed in control plots. The plant height in treatments T_3 and T_6; T_7, T_9 and T_{10} were statistically similar.

The plant height varied from 25.79 to 36.93 cm after 60 days after planting. The tallest plant was recorded in the treatment T_6 while the shortest in control plots. There was highly significant difference among the treatments T_1, T_2, T_3, T_6, and T_7. The statistically similar treatments are T_2, T_4, T_8 and T_9.

At 75 DAT, the plant height ranged from 26.44 to 38.23 cm. The tallest plant was recorded in treatment T_6 while the shortest in the control plots. The difference was highly prominent among the treatments T_1, T_2, T_3, T_6 and T_9. The plant height in treatments T_2, T_4, T_5 and T_8 were statistically similar. Plant height was slightly reduced at harvest. It varied from 26.31 to 37.89 cm. The decreasing rate was slow comparing with the increasing rate of previous growth. The tallest plant was recorded in T_6 as before which was followed by T_3, T_{10} and T_7. The results indicated that sulphur, zinc or molybdenum had no effect while boron had significant effect on plant height at this growth stage.

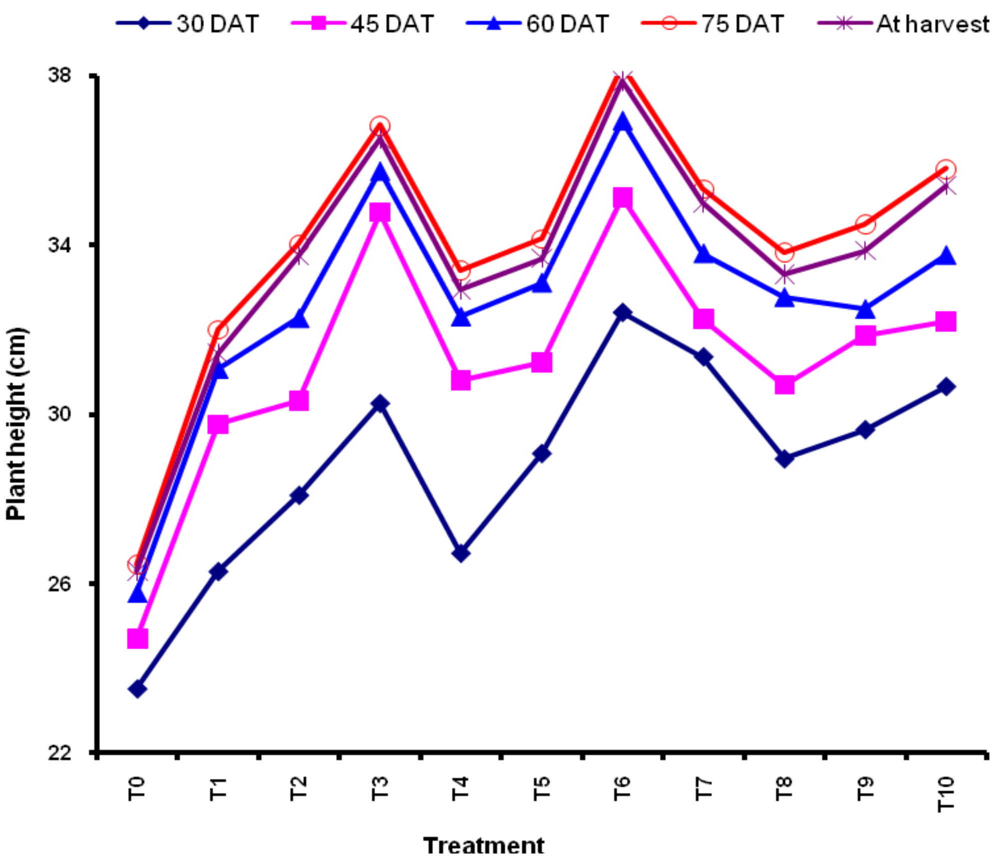

Figure 1.4.2: Height of the cabbage plant as influenced by different nutrient combinations.

1.4.1.3 Length of largest leaf

The size of leaf is an important growth parameter of cabbage which was significantly influenced due to different fertilizers (Fig. 1.4.3 and Appendix 6). The leaf length was measured at 30, 45, 60, 75, and at harvest. The growth of leaves was increased with passage of time. The leaf length was rapidly increased up to 60 days, then slowly increased up to 75 days and finally it was decreased at harvest.

At 30 DAT, the size of leaves ranged from 17.83 to 26.19 cm. The added N, P, K and B significantly increased leaf length. The largest leaf was found when B was added to the soil while it was lowest in control plots. The results indicated that B as boric acid is directly absorbed by plants at initial stage. However, there was highly significance correlation among the treatments T_1, T_2, T_4 and T_6. Treatments T_3, T_4, T_7, T_8 and T_9; T_5 and T_{10} were statistically similar.

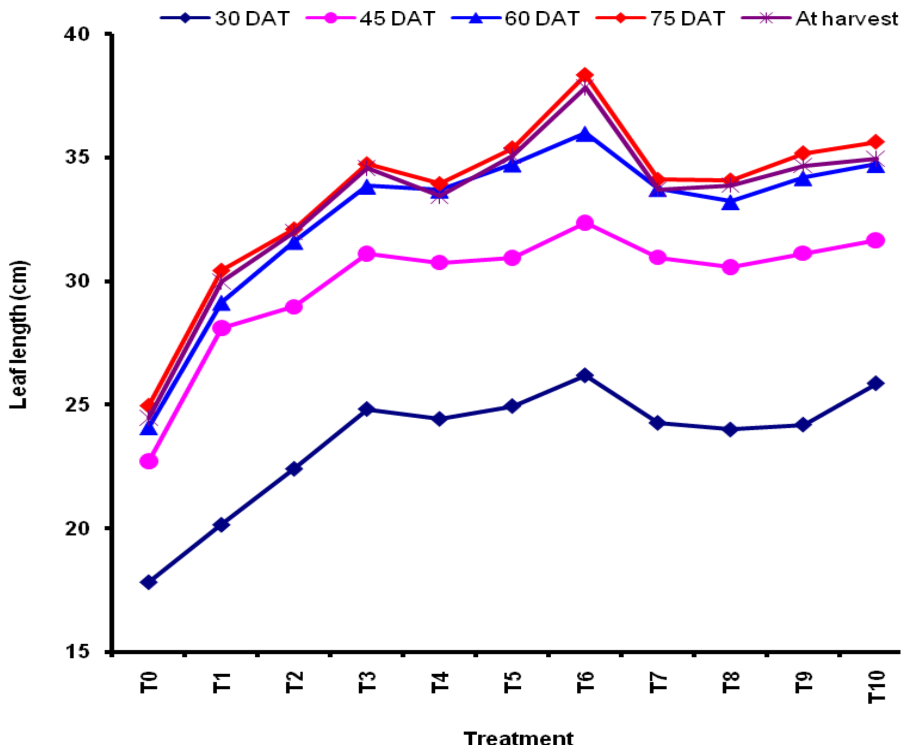

Figure 1.4.3: Length of largest leaf of cabbage at different growth period as influenced by different nutrient combinations.

The largest leaf (32.36 cm) was observed in plot which received N, P, K and B while the smallest (22.27 cm) in control plots after 45 days. The results showed that application of NPK + B significantly increased leaf size but S and Zn with NPK decreased the leaf size. The size of leaves in treatments T_1 and T_2; T_3, T_4, T_5, T_7, T_8 and T_9 were statistically identical.

The size of leaves was ranged from 24.09 to 35.97cm after 60 days. The largest leaf was observed in plots treated with B (T_6) while the smallest was recorded in control plots. The application of B with NPK significantly increased leaf size while addition of S and Zn with NPK decreased the leaf size. The leaf size was significant among treatments T_1, T_2, T_5, T_6 and T_8. The treatments T_3, T_4; T_7 and T_9; and T_5 and T_{10} were statistically similar.

The leaf size was ranged from 26.97 to 38.33 cm after 75 days. The largest leaf was found when NPK+B was applied at T_6 treatment followed by T_{10}, T_5, T_9, T_3, T_7, T_8, T_4, T_2 and T_1 respectively. The smallest leaf was recorded in the control plots. The treatments T_5, T_9 and T_{10} are statistically similar.

At harvest, the longest leaf was recorded (37.83 cm) in T_6 followed by T_5. The results indicated that boron had prominent effect while sulphur and molybdenum had no effect on the length of cabbage leaf when added with NPK.

1.4.1.4 Breadth of largest leaf

The breadth of leaves of cabbage is an important parameter for proper head formation. Different nutrient management had significant effect on the breadth of leaves (Table 1.4.3). The breadth was increased gradually up to 45 days and then rapidly from 45 to 60 days and slowly from 75 days. With a few exceptions, the breadth of the largest leaf was remarkably increased when B was added to the soil.

The leaf breadth ranged from 10.90 to 17.28 cm after 30 days. The highest was recorded in treatment T_6 whereas the lowest was recorded in control plots. The leaf breadth in the treatments T_3, T_4, T_5, T_7 T_8, T_9 and T_{10} were statistically similar.

The highest breadth (22.26 cm) was observed in T_6 followed by T_{10}, T_9 and T_8 at 45 days after planting. The lowest breadth was found in the control plots. The difference was prominent among the treatments T_1, T_3, T_4, T_6 and T_7. The breadth in treatment T_6, T_8, T_9 and T_{10} were statistically identical. The results showed that application of N, P, K, Zn & B increased leaf breadth but S showed negative response at this period.

Leaf breadth ranged from 16.18 cm to 25.93 cm after 60 days. The highest breadth (25.93 cm) was found in T_6 while lowest (16.18 cm) was found in control plots. In this growth period treatments T_1, T_2, T_4 and T_5, T_8, T_9, T_{10} ware statistically similar among themselves.

After 75days, the highest breadth (28.43 cm) was obtained when B was added to the soil i.e.T_6 while the lowest (16.58 cm) was found in control plots. The difference was high significant among T_1, T_2, T_6, T_9 and T_{10}. Treatments T_3, T_8, T_9 were statistically similar. The results revealed that N, P, K and B had positive response while S had negative response on leaf breadth of cabbage at this growth stage.

Table 1.4.3: Largest leaf breath of cabbage as affected by different nutrient management at different Days After Transplanting (DAT).

Treatments	Breath of largest leaf (cm) at				
	30 DAT	45 DAT	60 DAT	75 DAT	Harvest
T_0=Control	10.90d	12.01g	16.18e	16.58g	15.58g
T_1=N	11.75cd	14.53f	20.86d	23.03f	21.93f
T_2=NP	12.59bcd	15.25f	21.31d	24.67e	23.37e
T_3=NPK	15.50abc	18.19d	23.53c	26.87bc	25.84bc
T_4=NPKS	13.63abcd	16.67e	21.48d	25.41de	23.91de
T_5=NPKZn	15.93ab	20.33bc	23.90bc	26.23cd	25.23c
T_6=NPKB	17.28a	22.26a	25.93a	28.43a	27.13a
T_7=NPKMo	14.78abc	19.87c	23.54e	25.88cd	24.48d
T_8=NPKSZn	15.38abc	21.13ab	24.20bc	26.87bc	25.87bc
T_9=NPKSZnB	16.04ab	21.63a	24.68b	27.34b	26.34b
T_{10}=NPKSZnBMo	16.24ab	21.73a	24.68b	26.64c	26.38b
LSD ($P \geq 0.05$)	3.37	1.15	1.02	1.02	1.12
CV (%)	13.67	3.34	2.62	2.36	2.24

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

The leaf breadth ranged from 15.58 to 27.13 cm at the time of harvest. The maximum breadth (27.13 cm) of the largest leaf was obtained in T_6 and the lowest (15.58 cm) in control plots. The treatment T_3, T_5 and T_8 were statistically identical.

The results showed that S and Mo reduced the breadth in all growth period when added individually with NPK. On the other hand, Zn showed no significant variation in leaf breadth while B had positive effect on leaf breadth in all growth period monitored.

1.4.1.5 Number of loose leaves

The number of loose leaves significantly influence by different nutrient management (Table 1.4.4). The numbers of loose leave gradually increased with the passage of time and reached its peak at 75 DAT in all treatments.

Table 1.4.4: Number of loose leaves of cabbage as affected by different nutrient management at different DAT.

Treatments	Number of loose leaf at				
	30 DAT	45 DAT	60 DAT	75 DAT	Harvest
T_0=Control	11.80e	15.40e	15.47f	18.77cd	14.67e
T_1=N	12.13e	15.87cde	16.20ef	18.46d	16.36d
T_2=NP	12.83de	16.33bcde	17.13e	19.73b	18.53ab
T_3=NPK	13.80bcd	16.97abcd	19.10b	20.23b	18.33ab
T_4=NPKS	14.33abc	15.73de	17.33de	19.47bc	17.47c
T_5=NPKZn	14.93ab	16.80bcd	18.47bc	19.33bcd	18.33ab
T_6=NPKB	15.40a	18.13a	20.10a	21.80a	19.80a
T_7=NPKMo	13.80bcd	17.10abc	18.60bc	19.33bcd	16.33d
T_8=NPKSZn	14.00bcd	16.87bcd	18.07cd	19.40bcd	17.70c
T_9=NPKSZnB	13.00cde	17.31ab	18.63bc	19.97b	16.97d
T_{10}=NPKSZnBMo	14.33abc	17.30ab	18.50bc	19.33bcd	16.33de
LSD ($P \geq 0.05$)	1.228	1.11	0.85	0.85	0.88
CV (%)	5.27	3.90	2.76	2.55	2.36

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

The number of loose leaves ranged from 11.80 to 15.40 at 30 days after planting. The maximum number (15.40) was recorded in T_6 which was followed by T_5, T_4, and T_{10} while the minimum in control plots. The treatments T_4, T_5, T_6 and T_{10} are statistically similar. After 45 days, it was ranged from 15.40 to 18.13. The highest (18.13) was obtained in T_6 and the lowest in control plots. The treatments T_5 and T_8 and treatment T_9 and T_{10} are statistically similar.

The number of loose leaves after 60 days was ranged from 15.47 to 20.10. The highest number was found in T_6 which was followed by T_3, T_9, T_7, T_{10}, T_5, T_8, T_4, T_2 and T_1 while the lowest being recorded control plots. The treatments T_5, T_7, T_9 and T_{10} are statistically identical. The highest number (21.80) of leaves after 75 days was also found in T_6 and the lowest number of leaves was found in control plots. The number of leaves in treatments T_5, T_7, T_8 and T_{10} were statistically similar.

At harvest, the number of loose leaves ranged from 14.67 to 19.80. The highest number of leaves was found in T_6 while the lowest was recorded in the control plots. The results indicated that S and Mo had negative effect; B had positive effect while Zn had no effect on the number of loose leaves of cabbage at harvest when added individually with NPK fertilizers. Combinations of these micronutrients with NPK were not able to increase the number of loose leaves rather they decreased it.

1.4.1.6 Days required for head formation

Application of different nutrients and their combinations exhibited significant influence on head formation (Table 1.4.5). The control plots required the longest time (59.16 days) for head formation while NPKB required 43.89 days although it was statistically similar to NPKZn, NPKSZn and NPKSZnBMo. NPKS delays head formation. It required 49.46 days. Application of NPK showed the head formation time is 47.50 days. Alam (2006) reported that early head formation of cabbage was significantly influenced by the application of B fertilizer in calcareous soils of Bangladesh. It indicates that head formation of cabbage is sensitive to B, but inverse relation with S.

1.4.1.7 Days required for head maturity

It was observed that different fertilizer combinations had significant effect on the days required for head maturity of cabbage (Table 1.4.5). The cabbage grown in the plot receiving treatment T_6 required minimum days (88.92 days) for maturity although it was statistically similar with the treatments T_5, T_7, T_8, T_9 and T_{10}. Maturity of head was delayed in NPKS (93.33 days) as compared with NPK treatments (92.21 days).

It may be concluded that, B inhibits early maturity whereas S resist it in calcareous soils. The results are in partial agreement with the findings of Wang-Xiude *et al.* (1996).

Table 1.4.5: Effect of nutrients on growth and yield parameters of cabbage.

Treatments	Days required to head formation	Days required for head maturity	Wt. of root (g/plant)	Wt. of stem (g/plant)	Wt. of loose leaves (g/plant)	DM of loose leaves (%)	Dry matter of head (%)
T_0=Control	59.16a	106.19a	20.66g	22.48d	360f	9.20a	5.36d
T_1=N	53.34b	93.78b	26.30f	31.52bc	410e	8.71a	5.35d
T_2=NP	50.80c	92.17cd	30.52e	33.11ab	520c	9.31a	6.36ab
T_3=NPK	47.50d	92.21cd	35.61a	33.66a	570b	8.36a	5.62cd
T_4=NPKS	49.46c	93.33bc	31.89cde	32.55abc	640a	9.34a	5.42d
T_5=NPKZn	45.50ef	91.20de	32.88bc	31.91bc	506e	8.94a	6.53a
T_6=NPKB	43.89f	88.92e	32.21bcd	31.25c	511c	9.13a	6.24abc
T_7=NPKMo	46.62de	91.11de	33.30bc	31.31c	423e	8.54a	5.58cd
T_8=NPKSZn	45.56ef	90.75e	33.47b	32.12abc	470d	8.93a	6.62a
T_9=NPKSZnB	44.89f	90.17e	33.52b	32.49abc	460d	9.07a	6.33ab
T_{10}=NPKSZnBMo	44.89f	90.17e	33.52b	32.49abc	460d	9.07a	6.33ab
LSD ($P \geq 0.05$)	1.55	1.14	1.32	1.43	17.49	1.37	0.65
CV (%)	1.87	0.72	2.49	2.67	2.12	2.84	6.44

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

1.4.1.8 Weight of root

Root weight of cabbage plant was significantly affected by different fertilizer treatments (Table 1.4.5). The maximum weight (35.61g) was found in T_3 while the minimum was recorded in control plots (20.66g). The results indicated that application of N, P and K increased the weight of root whereas application of B, Zn and Mo had no such effect.

1.4.1.9 Weight of stem

The weight of stem was also significantly influenced by different fertilizers as root weight (Table 1.4.5). It varied from 22.48 to 33.66 g. The maximum weight (33.66g) was found in T_3 while the minimum was obtained from control (T_0). The results showed that application of N, P and K increased the weight of stem whereas application of B, Zn and Mo had no such effect.

1.4.1.10 Weight of loose leaves

Different nutrients had significant influence on weight of loose leaves (Table 1.4.5). The maximum weight of loose leaves (640g) was obtained from T_4 (NPKS) treatment whereas the lowest was recorded in control plots.

The results indicated that folding mechanism is directly related with nutrients. When B added with NPK, the weight of loose leaves decreased but start early head formation and head maturity. Application of S with NPK significantly increased the weight of loose leaves but delayed head formation and head maturity. The results are fully accordance with Haro and Sonoda (1981) and were partially supported by Bajwa and Sharma (1990), Tandon (1995) and Das (1999).

1.4.1.11 Dry matter of loose leaves

There was no significant effect of nutrients on the dry matter accumulation in loose leaves of cabbage (Table 1.4.5). The range was 8.36 to 9.34%. The highest dry matter (9.34%) was found in T_4 treated plot while the lowest (8.36%) was recorded in treatment T_3. It was observed that addition of P, K, S increased the dry matter while N, Zn, Mo decreased the dry matter. The results showed that N, Zn and Mo produced succulent and soft loose leaves of cabbage.

1.4.1.12 Dry matter of head

The dry matter of cabbage head was influenced by different nutrients (Table 1.4.5). It was varied from 5.35 to 6.62 %. The highest dry matter (6.62%) was recorded in treatment T_8 whereas the lowest in T_1. The results indicated that application of K, S and Mo decreased dry matter whereas P, Zn & B increased head dry matter of cabbage.

1.4.1.13 Diameter of cabbage head

The diameter of cabbage head at harvest was responded significantly to fertilizer application and was varied from 11.18 to 23.02 cm (Table 1.4.6). It was observed that the diameter of the head was increased when B was added with NPK i.e. T_6. The smallest head (11.18 cm) was obtained in control plots. NKPB significantly increased the head diameter while Zn and S decrease it. The results are in partial agreement with the findings of Islam *et al*. (1989), Singh and Nailk (1988), Yamada and Kamata (1989), Anonymous (1990), Akter *et al.* (1999), Ullah *et al.* (1999) and Sarker *et al*. (2003).

Table 1.4.6: Effects of N, P, K, S, Zn, B and Mo on the yield and yield components of cabbage.

Treatments	Head diameter (cm)	Head thickness (cm)	Weight of marketable head (g)	Yield (kg/plot)	Yield (ton/ha)
T_{0}=Control	11.18g	8.25f	650.16h	19.50h	26.27h
T_1=N	15.02f	9.27e	1078.04g	32.34g	43.56g
T_2=NP	17.51e	10.42d	1201.99f	36.06f	48.56f
T_3=NPK	19.72d	10.77cd	1298.05e	39.76e	53.55e
T_4=NPKS	20.17cd	11.37bcd	1418.80d	38.94d	52.45d
T_5=NPKZn	22.50ab	12.00ab	1779.51b	42.56b	57.32b
T_6=NPKB	23.02a	12.85a	1894.18a	56.83a	76.53a
T_7=NPKMo	20.57bcd	11.88ab	1661.46e	53.39c	71.90c
T_8=NPKSZn	20.97bc	12.16ab	1785.73b	49.84d	67.13d
T_9=NPKSZnB	21.50b	12.48ab	1827.06ab	53.57ab	72.15ab
T_{10}=NPKSZnBMo	21.50b	12.48ab	1827.06ab	54.81ab	73.82ab
LSD ($P \geq 0.05$)	0. 91	1.02	90.86	1.09	1.09
CV (%)	2.75	5.34	3.69	3.69	3.69

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

1.4.1.14 Head thickness

The thickness of cabbage head was influenced by nutrients although the variation was minimum than head diameter. The head thickness ranged from 8.25 to 12.85 cm (Table 1.4.6). It may be due to the characteristics of cabbage variety used. The thickness was maximum (12.85 cm), when NPKB was applied (T_6) to the soil. But it was not significant to NPKZn, NPKMo, NPKSZn, NPKSZnB and NPKSZnBMo.

1.4.1.15 Marketable head

The weight of marketable cabbage head responded significantly due to nutrients and was ranged from 650.16 to 1894.18g (Table 1.4.6). The heads were rapidly increased when Zn and B were added to the treatments and the heaviest head (1894.18g) was obtained from the treatment T_6 (NPKB). The lightest head was recorded in the control plots.

1.4.1.16 Yield

The yield of cabbage was significantly influenced by the application of different fertilizers (Table 1.4.6). Wide variation was noted in plot yield (19.50– 56.83 kg/plot) as well as total yield (26.27 to 76.53 t/ha) of cabbage. The marketable head yield had been converted into yield per hectare. The head yield is directly depends on head weight of cabbage. The highest yield (76.53 t/ha) was obtained from the treatment T_6 (NPKB) which was 191% higher than the control plots. There was no difference in the yield of treatments T_9 and T_{10}. The lowest yield was recorded in the control plots (T_0).

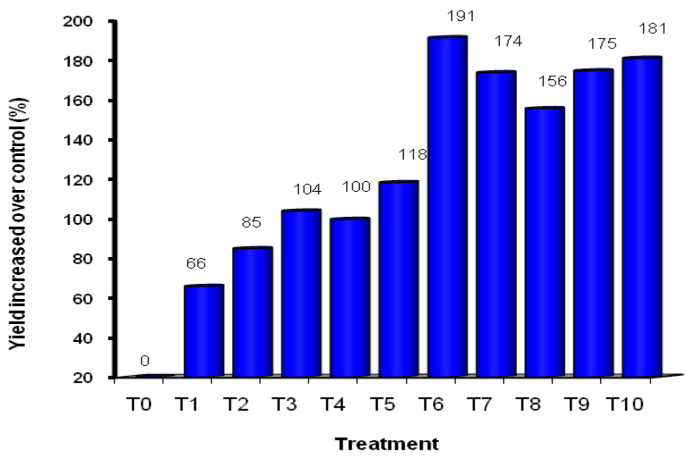

Figure 1.4.4: Increase of cabbage yield over control due to different nutrient management.

It was observed that N alone increased the yield by 66% while NP 85%, NPK 104%, NPKS 100%, NPKZn 118%, NPKB 191%, NPKMo 174%, NPKSZn 156%, NPKSZnB 175% and NPKSZnBMo 181% (Fig. 1.4.4) over control. It indicates that effect of S on cabbage is negative; N, P, K have good effect on cabbage production, Mo and Zn have significant effect on the production of cabbage and B has highly significant effect on cabbage production. The yield was highly increased when B was added to the soils as the head formation was highly associated with B.

The figure 1.4.5 indicates that the production was increased while Zn, Mo and B were added in a combination or separately with NPK (treatment T_3), but production was decreased when S was added with NPK.

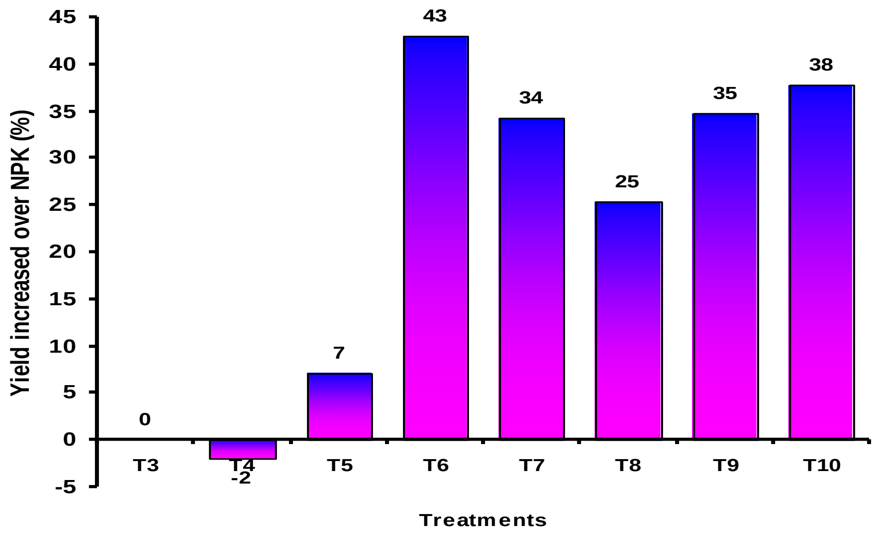

Figure 1.4.5: Increase of cabbage yield over NPK due to different nutrient management.

The results obtained in present study agrees partially with the observation of several investigators such as Singh and Nailk (1988), Yamada and Kamata (1989), Anonymous (1990), Kropisz (1992), Halim *et al*. (1994), Kamiyama *et al*. (1995), Sarker *et al*. (2002), Farid *et al*. (1998), Quattrucci and Canali (1998), Azad (2000) and Khan *et al.* (2002).

Experiment 2

Effect of micronutrient management on growth, yield and yield components of cabbage in calcareous soils of Bangladesh

1.4.2.1 Length of largest leaf

The leaf growth of cabbage was significantly influenced by micro-nutrients (Fig 1.4.6 and Appendix 7). At the early growth stage of 30 days it was varied from 26.73 to 30.70 cm. The longest leaf was recorded in T_2 although it was statistically insignificant with T_4 and T_5.

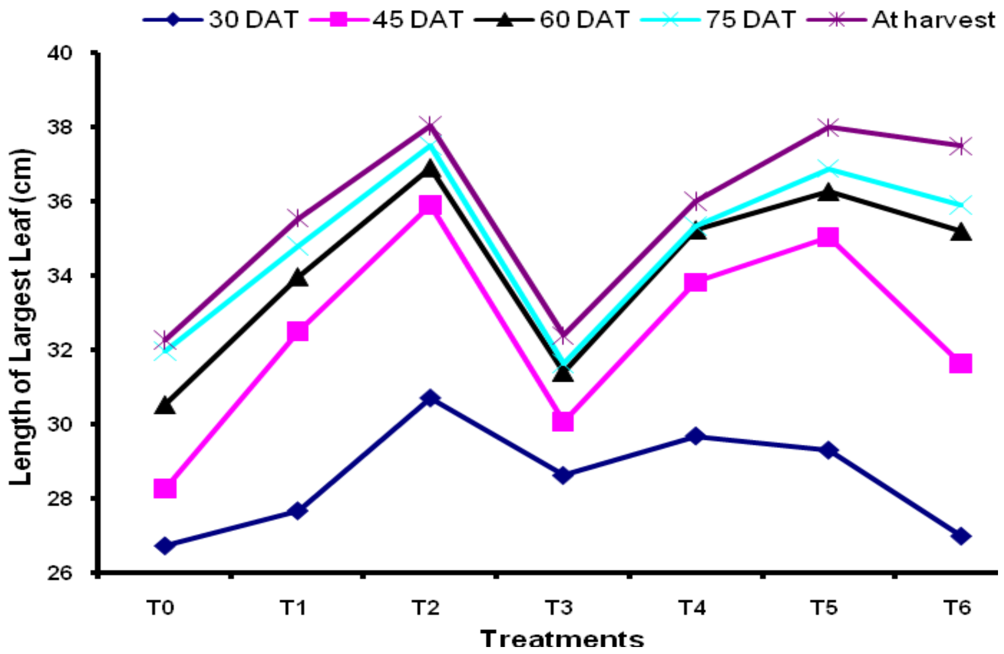

Figure 1.4.6: Length of largest leaf of cabbage at five growth period as affected by micro-nutrient management.

The shortest leaf was noted in control plots (T_0). The longest leaf after 45 days was monitored in treatment T_2 as before while the shortest in T_0. The treatments were clearly significant among themselves. After 60 days, the length was ranged from 30.53 to 36.90 cm. The longest was recorded in T_2 which was statistically identical with T_5. There was no statistical difference between the treatment T_4 and T_6. The trend of growth of cabbage leaf after 75 days was almost similar as observed in 60 days. At harvest, the longest leaf was recorded in T_5 which was statistically similar with T_2 and T_6. The shortest leaf was noted in T_0 and it was insignificant with T_3. There was no significant difference among the treatments T_1 and T_4.

The results indicated that the effect of Zn and B on leaf growth was insignificant at the early stage of 30 days, after which the increase was clearly visible in all growth period monitored. Addition of lower dose of Mo with lower dose of these nutrients produced good growth of leaf while higher doses of these three nutrients (T_3) decreased the leaf growth. The influence of Cu either lower or higher dose was more prominent only after 60 days up to the harvest of the crop. The performance of Mn was not satisfactory when added with Zn, B, and Mo.

1.4.2.2 Breadth of largest leaf

The leaf growth as indicated by breadth of the largest leaf was significantly affected by micro-nutrients (Table 1.4.7). After 30 days it was ranged from 18.05 to 21.93 cm. The widest leaf was recorded in T_2 although it was statistically similar with T_4. The narrowest leaf was produced by control plots while it was insignificantly differed from T_1, T_3, T_5 and T_6. Breadth of the largest leaf was varied from 24.75 to 29.04cm after 45 days. The widest was recorded in T_4 while the narrowest in T_0. The treatments T_1, T_3, T_5 and T_6 were statistically identical.

After 60 days, the widest leaf was produced by T_4 but it was statistically identical with all the treatments except the control plot. At 75 DAT, the leaf breadth was ranged from 26.94 to 34.71 cm. The widest was recorded in T_3 while the narrowest in T_0 which was insignificant with treatments T_5 and T_6. At the time of harvest the widest leaf (35.68cm) was produced by T_3 while narrowest (30.62 cm) by T_0 which differ insignificantly with the treatments T_1, T_4, T_5 and T_6.

It was observed that the rate of increase in leaf breadth was rapid up to 45 days after which it was much slower. The nutrients Zn and B increased the wideness of the leaf but in some growth period it was insignificant with the control plot. At the early growth stage the widest leaf was found in T_2 treatment while at the time of harvest widest leaf was noted in T_3. The results revealed that Zn, B, and Mo have positive effect on leaf wideness. The performance of Mn was satisfactory at the early stage while at late stage not satisfactory. The nutrient Cu did not show any effect on leaf wideness.

Table 1.4.7: Breadth of largest leaf of cabbage at five growth period as affected by micro-nutrient management.

Treatments	Breath of largest leaf (cm) at				
	30 DAT	45 DAT	60 DAT	75 DAT	Harvest
T_0 =control	18.05b	24.75c	26.94b	29.43d	30.62c
T_1=Zn_2B_2	19.33b	26.03b	28.98a	30.50bc	31.71bc
T_2= $Zn_2B_2Mo_{0.5}$	21.93a	28.63a	29.84a	31.32b	32.02b
T_3= $Zn_3B_3Mo_1$	19.09b	26.61b	28.74a	34.71a	35.68a
T_4= $Zn_2B_2Mo_{.5}Mn_4$	21.43a	29.04a	30.19a	31.16b	31.50bc
T_5= $Zn_2B_2Cu_1Mo_{0.5}Mn_4$	19.39b	26.09b	29.50a	30.10cd	31.29bc
T_6= $Zn_3B_3Cu_2Mo_1Mn_8$	18.74b	25.44bc	28.61a	30.14cd	31.25bc
LSD (0.05)	1.432	1.216	1.494	0.8513	1.189
CV (%)	4.08	2.56	2.90	1.54	2.09

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

1.4.2.3 Foliage coverage

The foliage coverage or the canopy diameter of cabbage was influenced by micro-nutrients (Fig. 1.4.7 and Appendix 8). At the early growth stage of 30 days the foliar coverage was ranged from 43.95 to 52.73 cm. The highest coverage was recorded in T_2 although it was statistically similar with T_4 (51.27 cm) and T_5 (52.07 cm). The treatments T_3, T_4 and T_5 were statistically identical. The lowest coverage was noted in T_0. After 45 days, the maximum coverage was monitored in the treatments T_2 (55.90 cm) and T_5 (55.90 cm) while the minimum in T_0 (47.78 cm). The treatments T_1, T_3 and T_4 were statistically identical. The maximum coverage after 60 days was recorded in T_5 followed by T_4. The treatments T_2 and T_3 were statistically identical. After 75 days, the trend of coverage was exact the same as monitored after 60 days. The highest coverage at the time of harvest was recorded in T_5 as observed in the previous growth period.

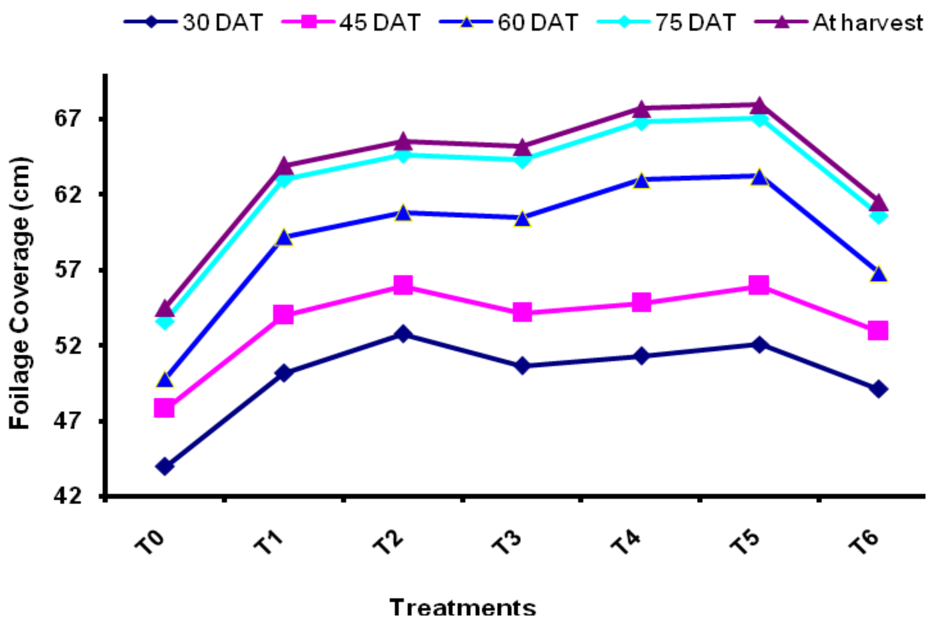

Figure 1.4.7: Foliage coverage of cabbage at five growth period as affected by micro-nutrient management.

It was observed that the rate of growth of cabbage plant as indicated by foliar coverage was satisfactory up to 75 days after which the rate was slower up to the end of growth. The effect of Zn and B was prominent in all growth period monitored. Lower dose of Cu (1 kg/ha) along with lower doses of other micro-nutrients (2 kg/ha Zn, 2 kg/ha B, 0.5 kg/ha Mo and 4 kg/ha Mn) increase the coverage while increasing doses of all nutrients decreased the coverage. Mo performed better only at the early stage while in late growth stage the effect was negligible.

1.4.2.4 Plant height

The micronutrients used in this investigation exhibited significant effect on the growth of cabbage plant (Fig. 1.4.8 and Appendix 9). At the early growth of 30 days height of cabbage plant ranged from 21.30 to 25.07 cm. The tallest plant was produced by the treatment T_2 which was statistically identical with T_3, T_4, T_5 and T_6. The range of plant height was 25.27- 28.61 cm after 45 days. The tallest plant was recorded in T_6 while the shortest in T_0. The treatments T_3, T_4 and T_6 were insignificant among themselves.

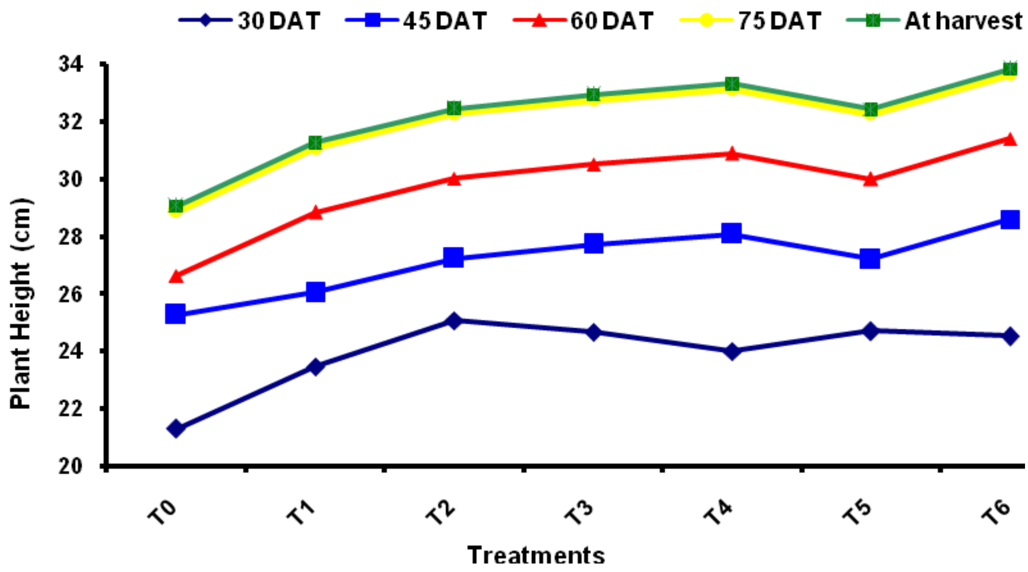

Figure 1.4.8: Height of cabbage plant at five growth period as affected by micro-nutrient management.

After 60 days, the tallest plant was produced by T_6 although it was statistically similar with T_3 and T_4. The treatment T_3, T_4 and T_5 were insignificant among themselves. Similar trend in plant growth was monitored after 75 days and at the time of harvest.

It was observed that Zn and B significantly increased the plant growth in all growth periods monitored except at 45 days. Mo at lower dose with lower doses of Zn and B performed better but at higher dose of these three nutrients did not to increase plant growth significantly. Lower dose of Zn, B, Cu, Mo and Mn performed better only at the early stage while higher dose of these nutrients performed best in all growth period. The results revealed that all the micro-nutrients contributed the height of cabbage plant.

1.4.2.5 Leaf weight

The weight of cabbage leaf per plant was significantly affected by micro-nutrients used in this investigation (Table 1.4.8). The highest weight (885.05g) was recorded in T_3 while the lowest (708.20g) in T_4. There was no significant difference among the treatments T_0, T_1, T_2, T_3, T_5 and T_6. Zn and B increased the leaf weight but insignificant with the control. Higher doses of Zn, B, Cu, Mo and Mn reduced leaf weight compared with the lower doses of the same nutrients.

1.4.2.6 Stem weight

Micro-nutrients used in this investigation were not able to show any significant effect on the weight of stem of cabbage plant (Table 1.4.8). The highest weight (73.89g) was recorded in control plots (T_0) while the lowest (50.72 g) in T_5 (Table 1.8). Other treatments produced intermediate weight.

1.4.2.7 Root weight

The root weight of cabbage was increased by the application of micro-nutrients but was insignificant (Table 1.4.8). The highest root was noted in T_6 although it was statistically similar with the control and the treatments T_1, T_3 and T_5. The effect of Zn and B was negative while the combination of all the micro-nutrients was slightly positive.

Table 1.4.8: Weight of leaf, stem and root of cabbage as affected by micro-nutrient management.

Treatments	Leaf weight (g) per plant	Stem weight (g) per plant	Root weight (g)per plant
T_0 =control	818.90ab	73.89a	46.67a
T_1=Zn_2B_2	870.82a	58.33bc	40.67ab
T_2= $Zn_2B_2Mo_{0.5}$	862.20a	57.56bc	33.3bc
T_3= $Zn_3B_3Mo_1$	885.05a	70.92ab	40.00ab
T_4= $Zn_2B_2Mo_{.5}Mn_4$	708.20b	56.62c	30.83c
T_5= $Zn_2B_2Cu_1Mo_{0.5}Mn_4$	820.65ab	50.72c	38.33abc
T_6= $Zn_3B_3Cu_2Mo_1Mn_8$	768.25ab	71.32ab	47.33a
LSD (0.05)	106.4	12.99	8.507
CV (%)	7.30	11.64	12.08

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

1.4.2.8 Head diameter

The diameter of cabbage head was ranged from 21.42 to 23.41 cm (Table 1.4.9). The highest diameter was recorded in T_2 which was statistically insignificant with T_4, T_3, T_5 and T_6. The effect of Zn, B and Mo at 2.0, 2.0 and 0.5 kg/ha level was significant with the control and T_1 while with other nutrients showed insignificant difference.

1.4.2.9 Head thickness

The thickness of cabbage head was ranged from 11.29 to 12.41 cm (Table 1.4.9). The highest thickness was recorded in T_2 which was statistically insignificant with T_1, T_4, T_3,

T_5 and T_6. The results indicated that ZnBMo is the most effective nutrient at 2.0, 2.0 and 0.5 kg/ha dose for thickness of cabbage head while Mn and Cu have negative relation.

Table 1.4.9: Yield and yield contributing characters of cabbage as affected by micro-nutrient management.

Treatments	Head diameter (cm)	Head thickness (cm)	Wt. of marketable Head (g/plant)	Gross weight per plant (g)	Total yield (t/ha)	Yield increase over control (%)
T_0=Control	21.42c	11.29b	1517.20c	2514.25b	61.28c	-
T_1=Zn_2B_2	21.66bc	11.62ab	1864.10b	2779.10a	75.33b	22.92
T_2= $Zn_2B_2Mo_{0.5}$	23.41a	12.41a	2181.20a	2997.15a	88.10a	43.76
T_3= $Zn_3B_3Mo_1$	22.89ab	11.74ab	1994.15ab	2917.00a	80.58ab	31.49
T_4= $Zn_2B_2Mo_{.5}Mn_4$	22.94ab	11.97ab	1995.25ab	2816.20a	80.61ab	31.54
T_5= $Zn_2B_2Cu_1Mo_{0.5}Mn_4$	22.47abc	11.92ab	1983.15ab	2812.00a	80.11ab	30.72
T_6= $Zn_3B_3Cu_2Mo_1Mn_8$	23.15a	12.15ab	1884.20b	2944.20a	76.12b	24.21
LSD (0.05)	1.329	0.8733	210.2	222.5	8.493	
CV (%)	3.31	4.14	6.16	4.43	6.16	

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

1.4.2.10 Weight of marketable head

Marketable head was significantly influenced by the micro-nutrients used (Table 1.4.9). The highest weight (2181.20 g) of marketable head was produced by T_2 although it was statistically insignificant with T_3, T_4 and T_5. The results exhibited that the effect of Zn, B and Mo is highly prominent on marketable head at 2.0, 2.0 and 0.5 kg/ha dose while Cu and Mn have negative effect.

1.4.2.11 Total yield

The yield of cabbage was significantly affected by the micro-nutrients and increased the yield from 22.92 to 43.76 % over control (Table 1.4.9). The highest yield (88.10 t/ha) as well as the highest increase (43.76%) was obtained from the treatment T_2 having $Zn_2B_2Mo_{0.5}$ although it was statistically identical with T_3, T_4 and T_5. The results exhibited that higher doses of Zn, B and, Mo reduced the yield as compared with the lower doses of these nutrients. Similarly, addition of Mn, Cu with Zn, B and Mo decreased the yield. The results revealed that Zn, B and Mo at 2.0, 2.0 and 0.5 kg/ha dose is the most effective nutrient for the highest production of cabbage. The results obtained in the present study agree with Sarma *et al*., (2002); Alam (2007) and Kanujia *et al*. (2006). All the investigators have been reported the positive effect of Zn and B on cabbage yield.

1.4.2.12 Gross weight

Gross weight of cabbage was significantly influenced by micro-nutrients (Table 1.4.9) ranging from 2514.25 to 2997.15 g/plant. The highest gross weight was obtained from T_2 which indicated that Zn, B, and Mo have positive impact on gross weight at the rate of 2, 2, and 0.5 kg/ha respectively as compared with control while other nutrients have negligible effect although all the treatments were statistically similar among themselves.

Summary and Conclusion

Experiment 1

The result showed that the plant spread, plant height, leaf length, leaf breadth were increased gradually up to 75 DAT and very slowly after 75 days. The highest plant spread (70.76 cm), plant height (37.89 cm), largest leaf length (37.83 cm), largest leaf breadth (27.13 cm), number of loose leaves (19.80 cm) were obtained from the treatment having NPK with B. For head formation, NPK took 47.50 days whereas NPKS showed 49.46 days and NPKB required 43.89 days. For head maturity, NPK required 92.21 days while NPKS required 93.33 days and NPKB 88.92 days. NPK produced 570 g/plant loose leaves, whereas NPKS produced 640 g/plant and NPKB 511 g/plant. All these indicate the head formation mechanism of cabbage. S enhanced the weight of loose leaves but not folds the leaves/head formation and head maturity. On the other hand, B folds the leaves for early head formation and maturity decreasing weight of loose leaves.

The maximum stem weight was found in the treatment having NPK. Boron, Zn and Mo had not positive effect on stem weight in this investigation. Application of S with NPK significantly increased the weight of loose leaves. The application of B decreased weight of loose leaves but increased the head weight of cabbage.

The dry matter of loose leaves was not significantly affected by different nutrient management although the highest was recorded in NPK with S. Addition of NPK increased the dry matter, but Zn, S, B, and Mo decreased it. The results showed that Mo, B, S, and Zn produced succulent and soft loose leaves of cabbage. The highest dry matter of cabbage head was recorded in NPK with Zn and S. The application of K, S and Mo decreased head dry matter but P, Zn & B increased it.

The head diameter was increased when NKPB was added to the treatments and decrease while Mo and S added. The thickness of cabbage head was maximized when NPKB was applied to the soil. The highest yield (76.53 t/ha) was obtained from the plants those received NPKB while the lowest was found in the control plots (26.27 t/ha). It was observed that effect of S on the yield of cabbage is significantly negative (NPK produced 53.55 t/ha and NPKS produced 42.45 t/ha); NPK have good effect on cabbage yield and B has very good effect on cabbage production.

Experiment 2

The results indicated that the effect of Zn and B on the length of leaf was insignificant at the early stage while it was significant in late growth period. Lower dose of ZnBMo (2, 2 and 0.5 kg/ha) produced good growth of leaf while higher doses (3, 3 and 1 kg/ha) of these nutrients or with other nutrients decreased the leaf growth. The influence of Cu either lower or higher dose was notable only after 60 days up to the harvest of the crop. From 60 days to harvest maximum leaf length was in $Zn_2B_2Cu_1Mo_{0.5}Mn_4$ (36.26, 36.88 and 37.97 cm at 60, 75 and harvest respectively). The performance of Mn was unsatisfactory when added with ZnBMo.

The nutrients Zn and B increased the wideness of the leaf but it was not consistent in all growth period. At early stage the widest leaf was found in treatment having lower dose of Zn, B and Mo while at the time of harvest it was noted in higher dose of the same nutrients. The results revealed that Zn, B, and Mo have positive effect on leaf wideness. The performance of Mn was satisfactory only at the early stage. The nutrient Cu did not show any effect on leaf wideness.

The effect of Zn and B on foliage coverage was prominent in all growth period monitored. Lower dose of Cu along with lower doses of other micronutrients increase the coverage while increasing doses of all nutrients decreased the coverage. Mo performed better only at the early stage.

It was observed that Zn and B significantly increased the plant height in all growth periods monitored except at 45 days than control. Mo at lower dose with lower doses of Zn and B performed better but at higher dose of these three nutrients did not increase plant growth significantly. Lower dose of Zn, B, Cu, Mo and Mn performed better only at the early stage 30 (DAT) while higher dose of these nutrients performed best in all rest period. The results revealed that all the micro-nutrients contributed the height of cabbage plant.

The leaf weight was increased by Zn and B but was insignificant. The highest weight of leaf was in $Zn_3B_3Mo_1$ (885.05 g/plant). The higher doses of Zn, B, Cu, Mo and Mn reduced leaf weight of cabbage (768.25 g/plant) compared with that of lower doses (820.65 g/plant). Micronutrients used in this investigation were not able to show any significant effect on the weight of stem of cabbage. The root weight of cabbage was increased by the application of micronutrients but was insignificant.

It was observed that Zn, B and Mo at 2.0, 2.0 and 0.5 kg/ha dose had the highest effect on head diameter (23.41cm), head thickness (12.41cm), weight of marketable head (2181.20 g/plant), gross weight (2997.15g/plant) and total yield (88.10 t/ha) of cabbage. The dose has increased 43.76% production over control (61.28 t/ha). The results exhibited that higher doses of Zn, B, Cu, Mo and Mn reduced the yield (yield is 80.58 t/ha) as compared with that of lower doses ($Zn_3B_3Mo_1$). Similarly, addition of Mn and Cu with Zn, B and Mo decreased the yield.

Chapter 2: Cauliflower

Experiment 1

EFFECT OF NUTRIENT MANAGEMENT ON GROWTH, YIELD AND YIELD COMPONENTS OF CAULIFLOWER IN CALCAREOUS SOILS OF BANGLADESH

Experiment 2

EFFECT OF MICRONUTRIENT MANAGEMENT ON GROWTH, YIELD AND YIELD COMPONENTS OF CAULIFLOWER IN CALCAREOUS SOILS OF BANGLADESH

Introduction

Cauliflower (*Brassica oleracea* var. *botrytis*) belongs to the family Brassicaceae, is one of the nutritious, familiar vegetable and famous for its shape. It is considered to be the important source of carotenoids. It has low fat and protects human cells from cancer development. Cauliflower can be grown in all types of soil with good soil fertility and good water regime. Because of over mining of the plant food elements by the crops, most of the micronutrients become in short-supply to the crops and some disorders appear resulting in low yields (Joshi 1997).

Constant attention should be given to micronutrient levels. A crop can suffer from nutrient deficiency without showing a specific symptom. If the symptom is evident, the crop is already suffering a deficiency and a yield reduction will result. It would be an economic safeguard to check-and-avoid or, at least, check-and-remedy any yield-robbing problems.

Some of the micronutrient required by cauliflower becomes unavailable if the soil condition is acidic such as molybdenum. In cauliflower boron deficiency has been reported very frequently (Som and Maity 1986). Cauliflower is highly sensitive to the deficiency of molybdenum in soils. Young plants become chlorotic, cup-shaped and finally wither. At the early growth stage, external symptom of boron deficiency is not apparent. The first sign is the small water soaked areas in the center of the curd. In later stages and in seriously affected plants, the stem becomes hollow water socked tissue surrounding the walls of cavity. In more advanced stages, pinkish and rusty brown areas develop on the surface of the curd which is known as red rot and result in low curd yield. Chatterjee (1986) recommend that this may be controlled by applying borax or sodium borate at the rate of 20 kg per hectare. He further reported that boron and molybdenum increased the curd size and weight. Ghimire (1991) obtained the highest yield (15.45 t/ha) with 22.5 kg borax per hectare. In another experiment, the highest curd yield (12.95 t/ha) was produced by snowball-16 cauliflower when the crop was supplied with 15 kg of borax per hectare (ARS 1992). In a similar study the highest curd yield (12.95 ton/ha) was obtained in the variety `Kibo giant' when the crop was fertilized with 25 kg of borax /ha (ARS 2002).

The requirement of Zn, B, Cu, Mn, Mo by the crop depends upon the variety and soil fertility status of the area. About two million hectares of net cultivable area of Bangladesh in different agro-ecological regions are deficient in zinc (Karim *et al.*, 1992). Therefore, it is necessary to determine the effect of Zn, B, S, Mo, Mn, Cu and some major fertilizers for good harvest of cauliflower. The present experiment was conducted with the following objectives:

i. To evaluate the effect of major nutrients such as N, P, K and minor nutrients such as Zn, S, B, Cu, Mn and Mo on the growth and yield of cauliflower;
ii. To compare the effect of micronutrients with macronutrients on the growth and yield of cauliflower; and
iii. To find out the optimum doses of fertilizers for maximizing yield potentiality of cauliflower.

Review of Literature

Cauliflower is an important vegetable crop which received much attention to the researchers in Bangladesh as well as in whole world to develop its production techniques. Many research works have been carried out in relation to nutrient management in different countries. However, few studies have been carried out on the effects of different macro and micro nutrient elements. A brief review of research works in relation to the effect of different macro and micro nutrient elements on growth, yield and quality of cauliflower are presented in this chapter.

2.2.1 Effect of Nitrogen, Phosphorus and Potassium

Perez and Loria (1975) studied the effects of NPK on cauliflower production. They found that the response of N, P, K was linear and there was no interaction. In first experiment, for each additional application of 75 kg N/ha (0, 150 and 300 kg) and 60 kg K_20/ha (0, 60 and 120 kg) production was increased by 1.54, 0.77 and 0.90 t/ha, respectively. In second experiment with the cv. Snowball W there was no response to applied N and K but the effect of P was quadratic.

Karim *et al*., (1997) studied the effect of different doses of NPK fertilizer as well as different levels of irrigation on plant `height, leaves, weight of curds, pods, seeds and seed yield of cauliflower**.** They concluded that the application of N, P and K significantly increased both curd (940.6 g/plant) and seed yield (32.5 g/plant) with increasing rate approaching 150 N, 112 P_20_5 and 100 K_20 (kg/ha).

Huang Meiqing (2007) reported the best application of NPK for maximum economic yield of cauliflower was 54.877 t/hm^2 with N=249.28, P_2O_5=54.33 and K_2O= 238.83kg/hm^2.

Cekey *et al*., (2011) investigated the effect of four different variants of nitrogen and suplhur fertilization on yield of cauliflower. They obtained the highest yield when it was fertilized with N:S = 250:60 kg.ha^{-1}. The increase of yield over untreated control was represented as 26.6%.

2.2.2 Effect of Boron

Mehrotra *et al*. (1975) observed increased curd size, curd weight and higher ascorbic acid content in cauliflower by foliar application of boron and ammonium molybdate.

Prasad and Singh (1988) obtained the highest yield (15.4 t/ha) in Pusa Snowball K-1 variety of cauliflower followed by Sel-5 (14.7 t/ha) with the lowest in K-19 (8.8 t/ha) under Boron application. Application of Boron significantly increased the yields (by 133%) curd weight, curd diameter, number of marketable curds and plant height.

Bajwa and Sharma (1990) reported that the application of gypsum, to Boron-rich acidic soil reduced Boron toxicity due to formation of calcium-borate complex and also due to increased soil permeability owning to leaching loss of Boron.

Batal *et al.* (1997) reported that application of Boron on clay loam soil from 2.2 to 8.8 kg/ha reduced hollow stem in cauliflower but had no effect on yield or curd mass. Application of Boron on sandy loam soil at 4.4 kg/ha gave maximum yield and curd mass, but the hollow stem disorder continued to decrease as Boron rates were increased up to 8.8 kg/ha.

Ghosh and Hasan (1997) reported that application of Boron as borax at 15 kg/ha on the cauliflower (cv. Early Kunwari) produced the highest number of leaves (27.2), the largest curds (1048 g) and the highest yield (524 quintal/ha).

A field experiments were conducted by **Singh and Kapoor (2002)** with cauliflower (cv. Snowball-16) in India. They observed that application of Boron up to 1.0 kg/ha significantly increased the yields. The symptom of Blackish curd was appeared in control plot. The highest Boron content in leaf tissue (23.77 mg/kg) and curds (19.31 mg/kg) was recorded upon treatment with 2.0 kg B/ha. Boron concentration in the leaf tissue was higher than that in the marketable curds. The hot water soluble boron in soil increased significantly from 0.47 to 0.83 mg/kg with increased rates of boron application in soil from 0.5 to 2.0 kg/ha over the control (0.21 mg/kg).

The effects of Boron (0, 5, 10, 15, 20 and 25 kg borax/ha) on cauliflower (var. Kibogiant) was evaluated by **Adhikary *et al.* (2004).** They obtained maximum plant height (42.05 cm) in plot which received 25 kg borax. It was 13.95% higher than the control plot. Maximum leaf (12.73) was observed in 10 kg borax. The maximum biomass production (1.06 kg plant$^{-1)}$ and maximum curd diameter (10.28 cm) was recorded in 25 kg borax.

The maximum curd production (10.9 t/ha) was observed in 25 kg borax. However, there was no significant difference in curd production among 15, 20 and 25 kg borax application.

2.2.3 Effect of Boron with others

Randhawa and Bhail (1976) found that 120 Kg N, 40 kg P and 15 kg of borax/ha gave the maximum yield.

Kotur (1992) investigated the response of two levels of lime and six levels of B on cauliflower production. He observed that Boron increased the curd yield by 59-90% over control and reduced curd rot from 52% (control) to 7% (1.5 kg/ha).

Mishra (1992) reported that application of 10 kg Boron/ha and 150 kg Nitrogen, increased significantly the seed weight and seed yield of cauliflower. There was a significant interaction between the effect of Nitrogen and Boron with highest seed yield (315 kg/ha and 279 kg/ha in two year) obtained with 150 kg Nitrogen + 10 kg Boron /ha.

The application of Boron (5.95kg Borax) or molybdenum (1.2kg ammonium molybdate/ha) to cauliflower had significantly enhanced curd yield and quality of ‘Soltany’ and ‘Amsheery’ cultivars **(Farage *et al*., 1994).**

Chattopadhyay and Mukhopadhyay (1998) investigated the effects of Boron at 0.28, 0.56 and 1.12 kg/ha as single or double spray, and Molybdenum at 0, 0.10, 0.20 and 0.40 kg/ha on cauliflower cv. Dania in West Bengal, India. They found that the highest rate of Boron produced the maximum curd yield (330.19q/ha). Curd yield was increased from 255.23 to 290.16 q/ha at the highest rate of Molybdenum. Plants supplied with Boron at 1.12 kg/ha and Molybdenum at 0.20 kg/ha produced the highest yield (336.63 q/ha).

The effects of Boron (10 and 20 kg Borax) and Molybdenum (0.5 and 1 kg sodium molybdate/ha), applied alone or in combination with 25 tons FYM/ha, on the yield and yield components on cauliflower cv. Pusa Snowball-1 was investigated by **Sanjay *et al*., (2002).** They observed that molybdenum and boron application significantly increased curd diameter, weight and yield in the absence of FYM. Boron at 10 kg/ha and molybdenum at 0.5 kg/ha increased the yield by 32 and 14% respectively. Application of FYM in addition to 100% recommended NPK enhanced the yield by about 27% compared to application of NPK alone.

2.2.4 Effect of Zinc

The effect of B and Zn on the yield and nutrients uptake of cauliflower was studied by **Varghese and Duraisami (2005).** The highest curd yield of 28.79 ton ha^{-1} was realized by the application of 1.0 kg B ha^{-1} and 2.5 kg Zn ha^{-1}, which was 35.5% higher over the control. The combined application of these nutrients beyond these levels tended to reduce the curd yield. Application of 1.0 kg B ha^{-1} with 2.5 kg Zn ha^{-1} was found to be better than individual application in terms of nutrient uptake and soil fertility. Application of B increased the availability of all nutrients, while the application of Zn especially at higher level (5.0 kg Zn ha^{-1}) decreased the availability of Cu and Fe.

2.2.5 Effect of Molybdenum

Singh and Rajput (1976) reported that 1.0 ppm molybdenum produced the tallest plant, increased the fresh and dry weight of plant, leaves, stem or root; diameter and length of the curd; yield and yield-contributing characters and nitrogen content of cauliflower. The lowest values were obtained from unfertilized control plots. Reducing and non-reducing sugars and ascorbic acid were favorably enhanced at 0.5 ppm molybdenum. The lowest values for sugars and ascorbic acid were observed under 1.0 ppm and nil molybdenum respectively. **Gyul'akhmedov *et al.*, (1977)** have reported that the optimum level of molybdenum increase yield of cauliflower seeds.

Kotur (1998) observed increased leaf width of cauliflower cv. Pusa Snowball I from 12.0 to 13.3 cm, curd diameter from 16.8 to 18.8 cm, curd weight from 710 to 804 g and leaf molybdenum concentration from 0.71 to 11.48 µg/g when the rate of molybdenum increased from 0 to 0.20%. Curd yield/ha was the highest with 0.10% Mo while curd size and leaf molybdenum concentration increased with the number of applications. A quadratic relationship was observed between curd yield and leaf molybdenum concentration and on that basis the maximum curd yield occurred at 6.73 µg Mo/g in the leaf.

Mello and Minami (1999) observed that the weight of curd (640.7 g) and yield (12.8 t/ha) of cauliflower (cv. Shiromaru II) were increased 28.7 and 32% respectively, than in the treatment where lime was not applied to the soil. Number of leaves and plant height were not affected by molybdenum and lime application.

Cauliflower is highly sensitive to the deficiency of molybdenum in soils. Young plants become chlorotic, cup-shaped and finally wither. If such symptoms are observed despite the basic doses have been given, a foliar spay of 0.2% molybdenum may correct the deficiency reported by **Rashid and Singh (2000).**

Mohamed *et al*., (2011) studied the effect of foliar spray of molybdenum and magnesium on cauliflower production in Egypt. They reported that 30 and 45 µg/l Mo significantly improved vegetative growth and curd yield while application of 0.50 and 0.75% Mg significantly enhanced foliar fresh weight, plant height, leaves fresh weight and leaves dry weight, total and marketable curds yield. They commented that molybdenum and magnesium are important and essential elements for the cauliflower production under Egyptian soil conditions.

2.2.6 Effect of Magnesium

Donahue *et al.* (1983) reported that cauliflower have high Magnesium (Mg) requirements.

2.2.7 Effect of nutrient combination

The seeds of cauliflower cv. Rannyaya Gribovskaya was soaked for 6 hours in 0.01 per cent solutions of Mn, Cu, Co, Zn, B, Mo or a mixture of minor elements by **Gyul'akhmedov *et al*., (1977).** They obtained the maximum yield 35-42 t/ha from those seeds and seedlings both were treated with the micronutrients.

Panigrahi *et al*. (1990) studied the effect of NPK, Boron, Molybdenum and lime on cauliflower production. They observed that application of 0.2% B as a seedling root dip with 1 kg B/ha applied to the soil resulted in the highest seed yield (2.05 q/ha) and a 97% increase in cauliflower diameter compared with the control (NPK fertilizer). Application of Mo and lime had no effect on cauliflower size. Liming increased seed yield whereas Mo had no effect.

Abedin *et al*., (1994) studied the sustainable practices in pest control, fertilization and soil erosion control of 85 selected farmers in Cameroon. Results indicated that use of less agricultural chemicals and inorganic fertilizers were more sustainable practices and framers who used these did not suffer yield sacrifices.

Tandon (1995) mentioned the antagonistic relationship among B-Ca, B-Mg and B-Mn, whereas B-S interaction both synergistic and antagonistic. He also reported that no deficiency or toxicity symptom of Boron was observed at Ca/B ratio of 365-1578. On the other hand, organic matter application on Boron deficient soil along with B increases the retention in soil by forming complexes.

Talukder (2000) reported that the maximum curd yield of 21.50 ton/ha of cauliflower in 1996-97 and 26.68 ton/ha in 1997-98 with an average of 24.10 ton/ha was obtained from the combination of 40 kg S, 1 kg B and 0.5 kg Mo/ha. A blanket dose of 100-60-100 kg/ha N, P_20_5 and K_2O respectively, were used in both the years.

Jana and Mukhopadhaya (2002) conducted an experiment on the effect of boron, molybdenum and zinc on yield and quality of cauliflower seed. They reported that higher seed yield and seed quality were observed by applying boron at the rate of 20 kg Borax per hectare as compared with no boron application. The combined effect of boron, molybdenum and zinc showed significant increase in number of primary inflorescence stalks (8.7 per plant), pods per plants (1085.7) and seed yield (489.3 kg/ha).

Noor *et al*., (2002) obtained the highest yield (36.53 t/ha) of cauliflower from the treatment containing chemical fertilizer (N_{150} P_{45} K_{90} S_{20} Zn_5 B_2 Mo_l kg/ha) followed by 50% chemical fertilizer + cowdung (10 ton/ha). However, chemical fertilizers alone contributed 284% while 50% chemical fertilizer + cowdung produced 219% higher yield over control. They pointed out that NPK fertilizer along with cowdung may be suitable for the marginal farmers. They suggested that addition of 10 t/ha cowdung instead of 50% recommended dose of chemical fertilizer able to produce satisfactory higher yield.

Materials and Methods

Two experiments were conducted to investigate the effect of nutrient management on cauliflower yield in calcareous soils of Bangladesh. First experiment was done from November 2008 to February 2009 and second experiment was done from November 2009 to February 2010. This chapter describes the materials and methods of these experiments which include a short description of experimental site and soil, climate, planting materials, layout of treatments, manure and fertilizations, intercultural operations, weed and pest management, data collection, harvesting and statistical analysis. The details of these are described below.

2.3.1 Experimental Site and Soil

The present investigation was conducted at the Horticulture Centre, DAE, Kallyanpur, Chapai Nawabganj, Bangladesh. The experimental field was medium high land belonging to the High Ganges River Floodplain (AEZ-11) and soil series was Sara (BARC, 2005). The soil sample (0-15cm) was collected and analyzed of soil texture by Hydrometer method and other parameters by Hunter (1984) from SRDI (Soil Resources Development Institute), Regional Lab, Shaympur, Rajshahi. The physico-chemical properties of the soil of the experimental plots are presented in Appendix 2.

2.3.2 Climate

The climate of the experimental site is subtropical in nature, which is characterized by three distinct seasons, the monsoon extending from May to October, the winter or dry season from November to February and pre-monsoon period hot season from March to April. The seasonal condition comprises of sufficient precipitation during the months from April to September and scant or no rainfall during the rest of the months of the year. Plenty of sunshine and moderate low temperature prevails during Rabi season from October to March which is suitable for growing Rabi vegetables in Bangladesh.

Information regarding monthly maximum and minimum temperature, rainfall, relative humidity, soil temperature as recorded by the Regional Horticulture Research Station, Chapi Nawabganj during the study period has been presented in Appendix 3a and 3b.

2.3.3 Land Preparation

The selected land was opened on 1 November, 2008 for the first experiment and on 4 November 2009 for the second experiment with a power tiller and it was exposed to the sun for 7 days prior to next ploughing. Thereafter, the land was ploughed and cross ploughed several times by a Power tiller to obtain a good tilth. All ploughing operations were followed by laddering for breaking up the clods and leveling the surface of the land. Weeds and stubbles were removed from the field just after every laddering.

2.3.4 Treatments of Experiment

A total of 11 treatments including the untreated control were selected in experiment 1 while in experiment 2 include only 7 treatments. The experimental treatments were as follow:

Experiment 1

T_o = Control
T_1 = N
T_2 = NP
T_3 = NPK
T_4 = NPKS
T_5 = NPKZn
T_6 = NPKB
T_7 = NPKMo
T_8 = NPKSZn
T_9 = NPKSZnB
T_{10}= NPKSZnBMo

Experiment 2

T_0 = Control
T_1 = Zn_2B_2
T_2 = $Zn_2B_2Mo_{0.5}$
T_3 = $Zn_3B_3Mo_1$
T_4 = $Zn_2B_2Mo_{.5}Mn_4$
T_5 = $Zn_2B_2Cu_1Mo_{0.5}Mn_4$
T_6 = $Zn_3B_3Cu_2Mo_1Mn_8$

NB: 0.5, 1, 2, 3, 4 and 8 indicated Kg per hectare, where N_{150}, P_{50}, K_{100} were applied as basal dose.

2.3.5 Dose, source and methods of application of nutrients

The doses and sources of the fertilizers were applied into the experimental 1 and 2 were as follows:

Table 2.3.1 Dose of different nutrients applied to the experiment 1.

Name of nutrient elements	Dose (kg/ha)	Source of Fertilizer	% Nutrient
N	150	Urea = $CO(NH_2)_2$	N = 46
P	50	TSP = $Ca(H_2PO_4)_2$	P = 21
K	100	MOP = KCl	K = 50
S	20	Gypsum = $CaSO_4.2H_2O$	S = 18
Zn	3	Zinc oxide = ZnO	Zn = 78
B	3	Boric acid = H_3BO_3	B = 17
Mo	1	Ammonium molybdate = $(NH_4)_6MO_7O_{24}.2H_2O$	Mo = 54

Table 2.3.2 Dose of different nutrients applied to the experiment 2.

	Dose (kg/ha)				
Treatment	Zn	B	Mo	Cu	Mn
T_0 = Control	-	-	-	-	-
$T_1 = Zn_2B_2$	2	2	-	-	-
$T_2 = Zn_2B_2Mo_{0.5}$	2	2	0.5	-	-
$T_3 = Zn_3B_3Mo_1$	3	3	1	-	-
$T_4 = Zn_2B_2Mo_{.5}Mn_4$	2	2	0.5	-	4
$T_5 = Zn_2B_2Cu_1Mo_{0.5}Mn_4$	2	2	0.5	1	4
$T_6 = Zn_3B_3Cu_2Mo_1Mn_8$	3	3	1	2	8

As basal dose of 150 kg N, 50 kg P_2O_5 and 100 kg K_2O was applied in experiment 2. The source of Mn was Manganese oxide and Cu was cupper sulphate. The whole amount of TSP, gypsum, zinc oxide, boric acid, ammonium molybdate, maganese oxide, cupper sulphate and 50% of urea and MOP were applied at final plot preparation. Rest MP and urea were applied in two equal installments at 15 and 35 days after planting of seedlings followed by irrigation.

2.3.6 Experimental Design and Layout

The experiments were laid out in randomized complete block design with three replications. Each block was divided into eleven plots in experiment 1 and seven in experiment 2. The treatments were allotted randomly into these plots. Thus, there were 33 unit plots in experiment 1 and 21 in experiment 2. The size of the unit plot was (3.3m x 2.25m). The distance between the blocks were 1.0 m and 0.5 m width drain was made between two adjacent plots. The plots were raised up to 15 cm.

2.3.7 Planting materials

The seedling of cauliflower (cv. white beauty) used in the experiments were collected from Horticulture Centre, DAE, Kallyanpur, Chapai Nawabganj, Bangladesh.

2.3.8 Preparation and planting of seedling

Thirty days old seedlings were transplanted in the experimental plots on 10 November 2008 in the first experiment and on 13 November 2009 in the second experiment, with a spacing of 55 cm x 45 cm. To avoid damage of the roots, seedbeds were watered in the morning before uprooting the seedlings and transplanted in the afternoon of the same day. After transplanting, seedlings were lightly watered. The young transplanted seedlings were kept under pieces of banana leaf sheath during the day time to protect their scorching by sunshine and opened at night to allow them receiving dew. Shading and watering were continued for 3 days until the seedlings were established.

2.3.9 Intercultural operations

2.3.9.1 Weed and Pest Management

Cutworm attack was the problem after transplanting the seedlings. Malathion 57 EC @ 2ml/L was sprayed to control the insects. The plots were kept weeds free by hand weeding whenever necessary.

2.3.9.2 Irrigation

Irrigation was applied by observing the soil moisture condition. However, each top-dressing was followed by irrigation. The irrigation was done 3 times carefully of each unit plots at 15, 35, 55 DAT.

2.3.9.3 Gap filling

Transplanted seedlings were monitored regularly to find out any damage or dead seedlings for replacement. Dead seedlings were replaced with the border plants kept for this purpose when required.

2.3.10 Harvest of crop

Harvesting of cauliflower was not possible in a particular day because of curd initiation as well as maturation was completed in different dates. The central curd was harvested when the plants formed compact curd. Harvesting was done from 20 January to 02 February 2009 in the first experiment and from 24 January to 05 February 2010 in the second experiment.

2.3.11 Methods of data collection

Ten plants were selected at random from each unit plot to collect the experimental data. The plants in the outer rows and at the extreme end of the middle rows were excluded to avoid the border effect. The following observations were made regarding plant growth, yield and yield attributes as affected by the different nutrient elements.

2.3.11.1 Number of leaves

All the leaves of the plants were counted separately from ten randomly selected plants of each plot. It was recorded periodically at 15 days interval.

2.3.11.2 Plant height

Plant height was measured from the point of the attachment of the leaves to the ground level up to the tip of the leaf. In recording plant height, length of the largest leaves was considered.

2.3.11.3 Fresh weight of leaves

Leaves were detached by sharp knife - at harvest and fresh weight was taken.

2.3.11.4 Spread of plant

Horizontal space covered by the plant measured in cm with a meter scale for determining spread of plant.

2.3.11.5 Number of loose leaves

The total number of loose leaves per plant was counted from 10 selected plants and mean value was recorded.

2.3.11.6 Length and breadth of largest leaf

Length of the largest leaf per plant was measured in cm with a meter scale from the base of the petiole to the tip. Breadth of the largest leaf also measured.

2.3.11.7 Fresh weight of stem, leaves and curd

The fresh weight of stem, leaves and curd were measured in gram (g) by weighting with a beam balance.

2.3.11.8 Diameter and thickness of curd

The curds from sample plants were sectioned vertically at the middle position with a sharp knife. The diameter of the curd was measured in centimeter (cm) with a meter scale as the horizontal distance from one side to other side of the widest part of the sectioned curd and mean value was recorded. The thickness of curd was measured in centimeter (cm) with a meter scale as the vertical distance from the lower to the upper most leaves of curd after sectioning it vertically at the middle position and mean value was found out.

2.3.11.9 Fresh weight of loose leaves at harvest

The fresh weight of loose leaves was taken which were present at the harvest time and expressed in gram and mean value for a unit plot was recorded.

2.3.11.10 Weight of marketable curd

The weight of the compact curds excluding the loose leaves was taken and means value was calculated as the fresh weight of marketable curd.

2.3.11.11 Gross and curd yield

The yield in kilogram per plot was converted into yield per hectare basis and was expressed in ton.

2.3.12 Statistical analysis

The collected data on different parameters were analyzed statistically using MSTAT C Statistical package programme. The means for all treatments were calculated and the analysis of variance of the characters under studid were performed by F variance test. The differences among the treatment means were evaluated by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Results and Discussion

Two experiments were carried out to investigate the effect of nutrient management on the growth and yield of cauliflower. The findings of two experiments are presented under separate heads.

Experiment 1

Effect of nutrient management on growth, yield and yield components of cauliflower in calcareous soils of Bangladesh

2.4.1.1 Number of leaves

The growth of cauliflower plants as affected by different doses of fertilizer combinations showed significant differences (Fig. 2.4.1 and Appendix 10). The total number of leaves/plant at 30 days after planting was increased with the number of fertilizer applied to the experimental fields. The minimum number (11.60) was recorded in control plots while the number was maximum (13.20) in plot fertilized with all fertilizer combinations. Other fertilizer combinations had no significant difference among themselves. The number of leaves was increased with the age of the plant. After 45 days, all the treatments under investigation significantly increased the number of leaves over control plot. The minimum number of leaves (15.80) was recorded in unfertilized control plots while it was highest (19.30) in T_9 (NPKSZnB) which was followed by T_2 (18.03). There were no significant differences in the production of number of leaves in treatments T_2, T_5, T_7, T_8 and T_{10}.

The highest number of leaves was produced by T_7 after 60 days of transplanting (22.25) which was statistically similar with T_3, T_6 and T_8. The lowest number of leaves was produced by control plot (19.55 at harvest) which was statistically similar with T_1, T_4, T_5,T_9 and T_{10}. At harvest, the maximum value was 23.0 (at T_7). But at 30 and 45 DAT the maximum values were at T_{10} (13.2) and T_9 (19.3) respectively. The results indicated that the production of leaves was increased significantly with the higher number of nutrient combinations only up to the middle stage of plant growth but at maturity stage the increase was minimal. The micronutrient used in this study had no significant effect on the production of leaves at the late growth stages compared to the NPK fertilizers.

Boron did not increase the number of leaves although Ghosh and Hasan (1997) obtained the highest number of leaves only at the rate of 15 kg/ha, the dose is 5 times higher than the present study. Similarly, Mello and Minami (1999) reported that number of leaves and plant height were not affected by molybdenum.

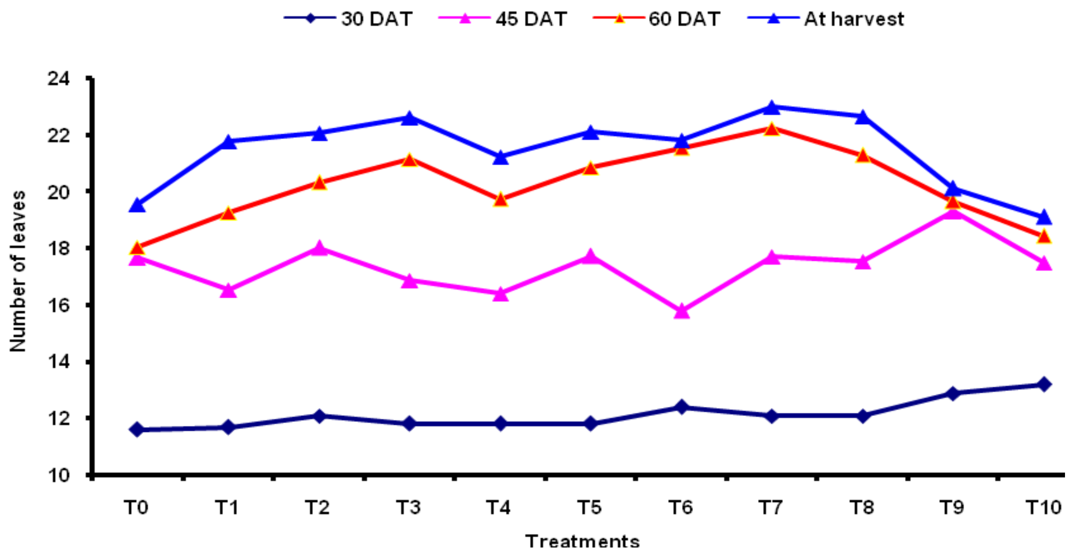

Figure 2.4.1: Number of leaves in cauliflower plants at different growth periods as affected by different fertilizer combinations.

2.4.1.2 Length of the largest leaf

It was observed that the fertilizer combinations under investigation had positive effect on the size of the leaves of cauliflower plants (Fig. 2.4.2 and Appendix 11). The longest leaf (31.90 cm) at 30 DAT was recorded in plant treated with all fertilizer combinations i.e. T_{10} which were followed by T_9 and T_4. The plants applied with nitrogenous fertilizer only (T_1) did not produce any significant increase in leaf size as compared to unfertilized control plants. The size of leaves of cauliflower plants was increased with the age of the plant. After 45 days, the longest leaf (36.57 cm) was recorded in plant received all fertilizer combinations (T_{10}) which was statistically identical with T_9. Similar trend in leaf size development was monitored at 60 days after planting. The longest leaf (42.18 cm) was recorded in T_{10} followed by T_9 (41.21 cm).

All the treatments significantly increased the size of the leaf of cauliflower at the time of harvest. The longest leaf was monitored in treatment T_{10} (44.63 cm) although it was statistically similar with T_9 (43.71 cm). The leaf size in T_3, T_4 and T_8 were statistically identical. Unfertilized plants always produced small leaves in all growth stages monitored. When Zinc, boron, and molybdenum were added individually with NPK (37.36, 36.22 and 35.75 cm respectively).

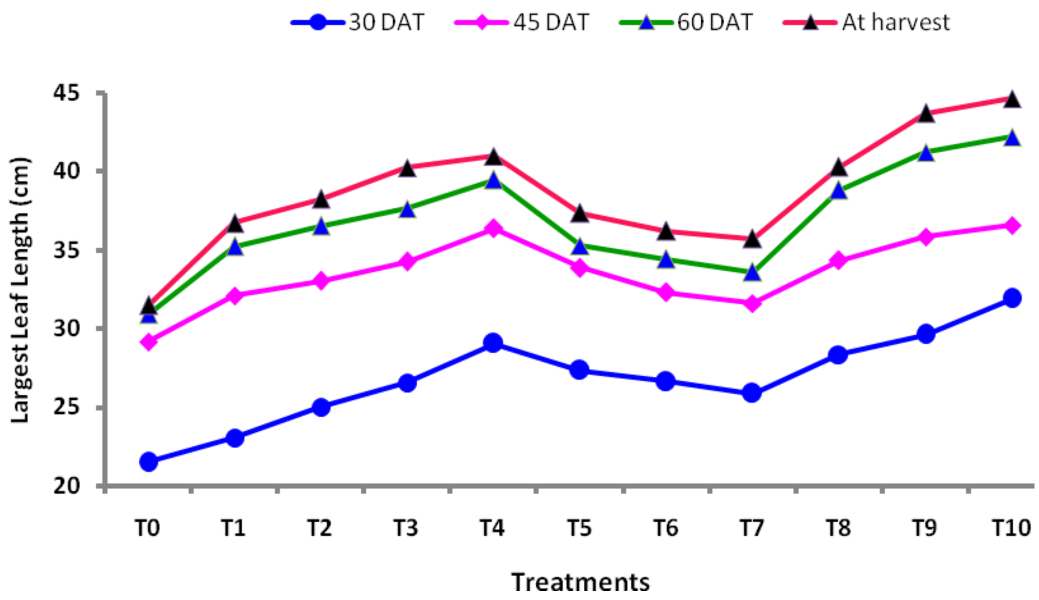

Figure 2.4.2: Length of the largest leaf of cauliflower at four growth periods as affected by different fertilizer combinations.

The results showed that when S added to NPK (T_4) increased leaf size at the late growth stages (40.97 cm) while other nutrients (Zn, B and Mo) reduced the leaf size. It revealed that micronutrients had interaction effect on leaf size of cauliflower but no individual effect.

2.4.1.3 Breadth of largest leaf

Breadth of the leaves of cauliflower plants was significantly influenced by different fertilizer applications (Fig. 2.4.3 and Appendix 12). The trend in development of leaf breadth was similar with the trend of length of the leaves as described in Fig. 2.4.2. Unfertilized control plants always produced narrow leaves in all growth stages while treatment T_{10} with NPKSZnBMo always produced widest leaves in all growth stages monitored. It was observed in general that the width of the leaves was increased with number of fertilizers applied to the cauliflower plants. The results revealed that the nutrients S, Zn and B increased the breadth of the largest leaf when added individually with NPK fertilizers.

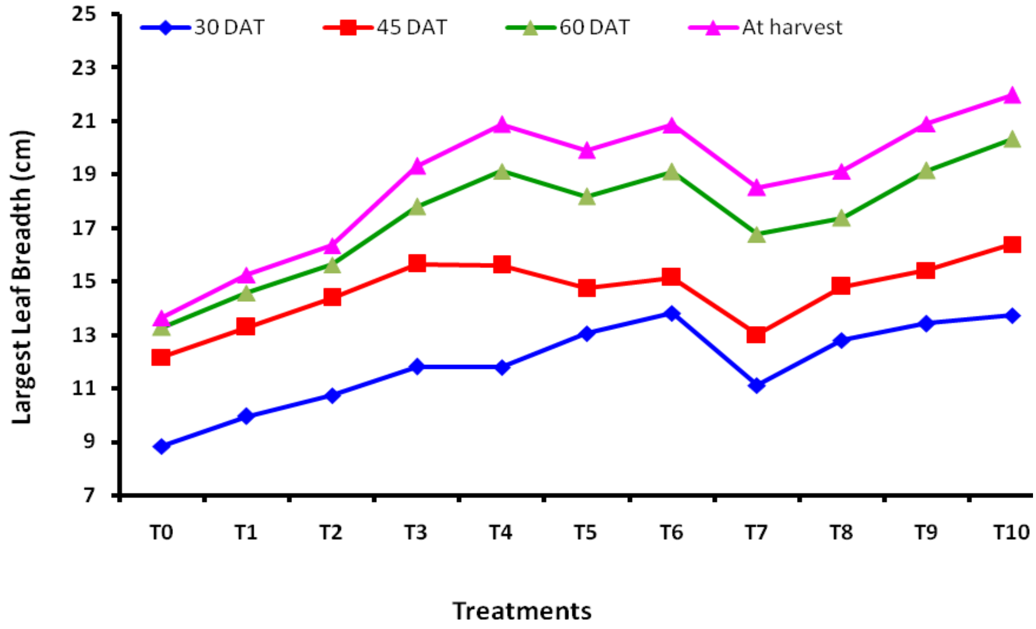

Figure 2.4.3: Breadth of largest leaf of cauliflower at four growth periods as affected by different nutrient combinations.

2.4.1.4 Spread of the plant

The application of different fertilizers had significant effect on the spread of cauliflower plants at different growth stages (Fig. 2.4.4 and Appendix 13). It was observed that combination of more fertilizers produced higher canopy diameter than the lower number of fertilizer combinations. The rate of spread of all plants was higher at the initial stage of growth while it was slower after 30 DAT. The highest spread of the plant (45.40 cm) as recorded at 30 DAT was obtained in treatment T_4 and T_{10}, although it was statistically identical with T_8. The lowest plant spread (39.97 cm) at 45 DAT was recorded in control plants while it was the highest (56.73 cm) in T_{10} which was followed by T_8 and T_6 and T_9. There was no significant difference in plant spread in T_6, T_8 and T_9. Similarly, the highest plant spread (63.73 cm) at 60 DAT was recorded in T_{10} and the lowest (41.95 cm) in control plots. There was no significant difference between treatments T_1 and T_2 and between T_8 and T_9.

All the treatments significantly increased spread of the cauliflower plant. The highest spread (65.45 cm) at harvest was recorded in T_{10} followed by T_8 although both of them were statistically identical. Control plants exhibited the minimum (42.65 cm) coverage. The results indicated that all the nutrients contributed on plant spread.

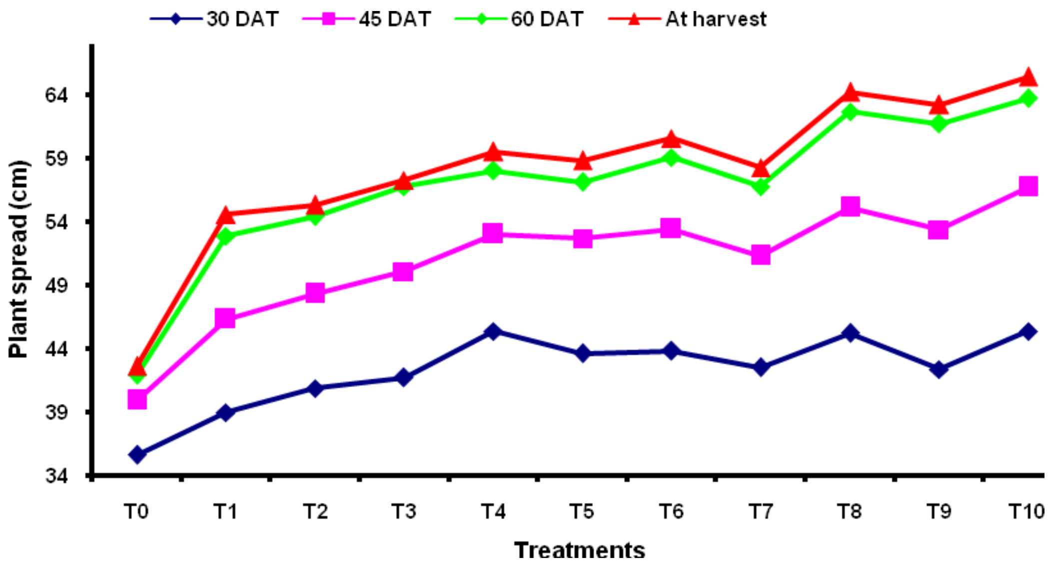

Figure 2.4.4: Spread of cauliflower plants at four growth periods as affected by different nutrient managements.

2.4.1.5 Plant height

The height of the cauliflower plant was remarkably influenced by the application of different fertilizer treatments (Fig. 2.4.5 and Appendix 14). The tallest plant (24.97 cm) at 30 DAT was produced by the treatment T_3 followed by T_4 and T_{10}. Control plots always produced the shortest plant in all growth period monitored. At 45 DAT, the maximum plant height was recorded in plots applied with NPKSZnB (T_9). It was observed that height of the plant in T_3, T_9 and T_{10} were statistically identical at this growth stage. The tallest plant (39.00 cm) at 60 DAT was recorded in T_6 followed by T_{10} and T_9 but they were statistically identical.

At harvest, all the treatments significantly increased the plant height. The tallest plant (44.78 cm) was produced by T_{10} while the shortest was recorded in control plot. The treatments T_2, T_4 and T_7 were statistically identical.

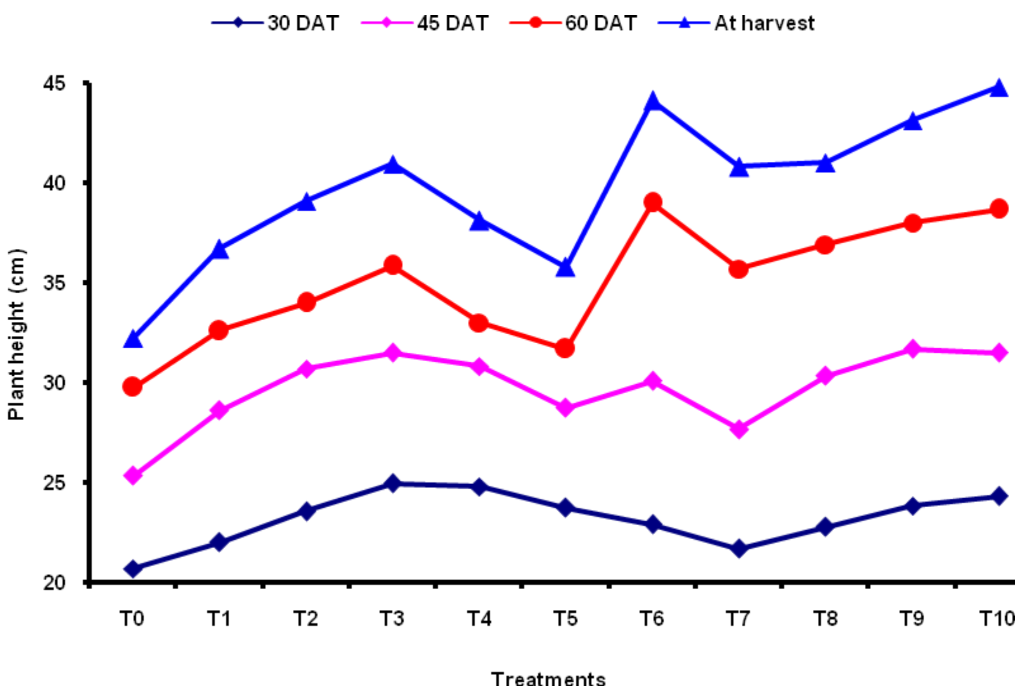

Figure 2.4.5: Height of cauliflower plant at four growth periods as affected by different fertilizer combinations.

The results indicated that sulphur, Zinc and molybdenum when added individually with NPK exhibited negative while boron showed positive effect on height of cauliflower plant. The combination of all nutrients produced the tallest plant which revealed that all of them have interaction effect on plant height. The result obtained agrees with Prasad and Singh (1988) and Adhikary *et al*. (2004).

2.4.1.6 Weight of leaves, Curd diameter and Curd height

The weight of leaves, curd diameter and curd height were influenced by different nutrient application (Table 2.4.3). The highest weight of leaves (710.07 g/plant) was obtained from T_6 although it was statistically identical with T_7 (695.54 g/plant). Weight of leaves in treatment T_3 and T_{10} as well as T_1 and T_2 were statistically identical. The lowest weight (195.63 g/plant) was obtained from control plants.

The largest diameter of curd (16.26 cm) was obtained from T_6 while the lowest (7.13 cm) was recorded in the control plots. However, the diameter of T_5, T_7, T_9 and T_{10} were statistically identical. Similarly, the treatments T_1, T_2, T_3, T_4, T_5 and T_8 were identical. The table shows that B increased the head diameter but S reduced it when added with NPK.

The highest curd height (9.73 cm) was monitored in T_6 although it was statistically identical with T_3, T_7, T_9, and T_{10}. The lowest (5.56 cm) was recorded in the control plots.

Table 2.4.3: Weight of leaves, curd diameter and curd height of cauliflower as affected by different nutrients.

Treatments	Weight of leaf (g/plant)	Curd diameter (cm)	Curd height (cm)
T_0=Control	195.63h	7.13e	5.56d
T_1=N	490.25fg	12.79d	8.71bc
T_2=NP	483.77g	12.87d	8.86bc
T_3=NPK	616.96b	13.82cd	9.01abc
T_4=NPKS	522.33e	12.81d	8.85bc
T_5=NPKZn	510.21ef	13.86bcd	8.64bc
T_6=NPKB	710.07a	16.26a	9.73a
T_7=NPKMo	695.54a	14.45bc	9.08abc
T_8=NPKSZn	546.85d	12.92d	8.48c
T_9=NPKSZnB	577.04c	15.04b	9.44ab
T_{10}=NPKSZnBMo	603.48b	14.71bc	9.08abc
LSD ($P \geq 0.05$)	21.40	1.11	0.77
CV (%)	2.32	4.87	5.22

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

All micronutrients with NPK reduced the weight of leaves (603.48 g/plant) than even NPK (616.96 g/plant). Curd height was increased by B and Mo while S and Zn decreased it when added individually with NPK.

2.4.1.7 Yield

The application of different nutrients had effect on all yield parameters such as curd weight, marketable curd weight and total yield of cauliflower (Table 2.4.4). The heaviest marketable curd (715.30 g/plant) was obtained from T_6 followed by T_7 (640.25 g/plant), T_3 (546.67 g/plant) and T_8 (521.11 g/plant). Treatment T_7 and T_9 were identical in weight of marketable curd. Control plots always produced the lightest curd.

Table 2.4.4: Yield and yield components of cauliflower plants as affected by different nutrient managements.

Treatments	Weight of Marketable Curd (g/plant)	Weight of Curd (g/plant)	Marketable Curd yield (t/ha)	Increase yield over control (%)	Increase yield over NPK (%)
T_0=Control	163.41g	122.97f	6.60g	-	-
T_1=N	426.67f	318.99e	17.24f	261.21	-
T_2=NP	495.56e	361.37cd	20.02e	303.33	-
T_3=NPK	546.67cd	373.61c	22.09cd	334.69	0.00
T_4=NPKS	437.78f	343.33de	17.69f	268.03	-19.92
T_5=NPKZn	503.33e	378.89c	20.34e	308.18	-7.92
T_6=NPKB	715.30a	499.78a	28.90a	437.87	30.83
T_7=NPKMo	640.25b	414.27b	25.87bc	391.96	17.11
T_8=NPKSZn	521.11de	360.32cd	21.05de	318.93	-4.71
T_9=NPKSZnB	640.19b	423.56b	25.88b	391.98	17.12
T_{10}=NPKSZnBMo	561.11c	433.93b	22.67c	343.48	2.63
LSD ($P \geq 0.05$)	25.76	24.94	1.04	-	-
CV (%)	2.94	4.00	2.94	-	-

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

The heaviest curd (499.78 g/ plant) was produced by T_6 followed by T_{10}, T_9 and T_7 although the last 3 treatments were statistically identical but significant with T_6. Similarly, the treatments T_2, T_3, T_5, and T_8 were insignificant among themselves. Control plots produced the lightest curd (122.97 g/plant).

The yield of cauliflower was significantly influenced by B. The highest yield (28.9 t/ha) as well as 437.87% higher than the control was produced by T_6 which was statistically significant with all other treatments. It was observed that addition of a single nutrient such as nitrogen only can produce 261.21% higher yield over control plots. But when S is added with NPK then yield decreased (19.92%) significantly than only NPK. Similarly Zn reduced 7.92% and SZn reduced 4.71%. The second highest yield (25.88 t/ha) was obtained from both the treatments T_7 and T_9.

The results showed that addition of Molybdenum to NPK increased 17.12% yield than only NPK. The yield of T_7 (NPK+Mo) and T_9 (NPKSZnB) are statistically identical which indicated that Molybdenum had influence on cauliflower yield. The result is similar to Singh and Rajput (1976); Kotur (1998); and Mello and Minami (1999). They reported higher yield of cauliflower at different doses of molybdenum as compared with the unfertilized control plots.

The table showed that treatment T_6 which is the addition Boron (NPK+B) produced higher yield than T_3. Similarly, the yield of T_9 (NPKSZnB) was higher than T_8 (NPKSZn) treatment. This result indicated that Boron had positive influence on the yield of cauliflower. Other investigators also reported positive effect of boron on cauliflower production. The result obtained in the present study agrees with Mehrotra *et al.*, (1975); Kotur, (1992); Ghosh and Hasan (1997); Singh and Kapoor (2002) and Adhikary *et al.*, (2004). Prasad and Singh (1988) reported that application of Boron significantly increased the yields (by 133%), curd weight, curd diameter, number of marketable curds and plant height.

2.4.1.8 Gross yield

Gross yield which includes total plant production was also varied due to the nutrient application but it maintained similar trend as monitored in yield of cauliflower (Table 2.4.5).

The highest weight of root (36.67g/plant) was obtained from T_7 and T_{10} which were statistically identical among themselves. Control plot produced lowest root (21.33g) which was identical with T_1. The highest weight of stem (65.56g) was recorded in T_6 and the lowest in control plots. The treatments T_5 and T_9, and T_3 and T_8 were statistically identical. The highest gross yield (17.89 t/ha) as well as the highest increase over control (378.22%) was recorded in T_9 followed by T_{10}. The results showed that S and Zn reduced the gross yield of cauliflower at harvest when added individually with NPK (T_3). Mo slightly increased the gross yield but it was insignificant. The results revealed that B had positive and significant effect on gross yield although some of the nutrients had no or insignificant effect on gross yield of cauliflower.

Table 2.4.5: Gross yield of cauliflower as affected by different macro and micronutrient management.

Treatments	Root weight (g/plant)	Stem weight (g/plant)	Gross yield (g/plant)	Increase gross yield over control (%)
T_0=Control	21.33e	35.00e	394.04i	-
T_1=N	22.33e	54.44d	971.36h	246.51
T_2=NP	27.33d	55.00d	1031.54g	261.73
T_3=NPK	30.33cd	59.44abcd	1222.51d	310.14
T_4=NPKS	31.67bc	56.67cd	1021.22g	258.98
T_5=NPKZn	33.67abc	62.22abc	1079.10f	273.78
T_6=NPKB	35.67a	65.56a	1490.92a	378.22
T_7=NPKMo	36.67a	64.45ab	1227.37d	311.41
T_8=NPKSZn	32.67abc	58.33abcd	1126.85e	285.83
T_9=NPKSZnB	34.33ab	62.67abc	1278.34c	324.31
T_{10}=NPKSZnBMo	36.67a	58.33bcd	1390.79b	352.85
LSD ($P \geq 0.05$)	3.60	6.40	38.77	
CV (%)	6.78	6.54	2.05	

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Experiment 2

Effect of micronutrient management on growth, yield and yield components of cauliflower in calcareous soils of Bangladesh

2.4.2.1 Length of largest leaf

The length of largest leaf of cauliflower was significantly affected by micro-nutrient management although the variation was negligible at early growth stages (Fig. 2.4.6 and Appendix 15). After 30 days, the length varied from 31.17 to 36.52 cm. The longest leaf was recorded in T_4 while the shortest in T_0. The leaf lengths were statistically similar in T_1, T_2, T_3, T_5, and T_6. Similar trend in leaf length was monitored after 45 days. The length of largest leaf was ranged from 42.61 to 49.41 cm after 60 days. The longest leaf at this growth period was obtained from T_1 while the shortest in T_0. The treatments T_3, T_4 and T_6 were statistically identical. At the time of harvest leaf length was affected by micro-nutrients. At this time the longest leaf was monitored in T_1 while the lowest in T_0 as the previous growth stage.

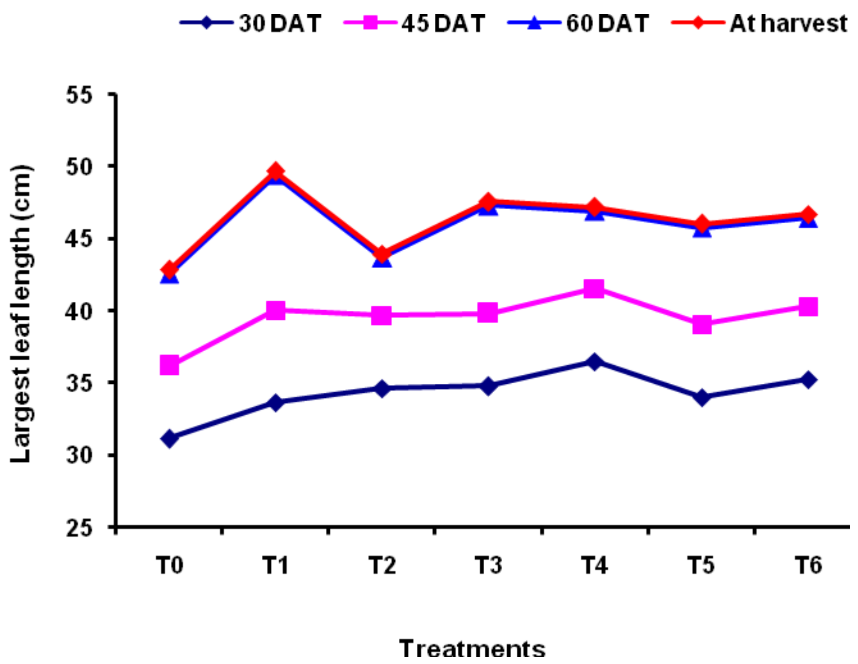

Figure 2.4.6: Length of largest leaf of cauliflower at different growth periods as affected by different micro-nutrient management.

The results indicated that the effect of Manganese was prominent and produced the longest leaf only at the early stage up to 45 days after transplanting. When the dose of Manganese or other nutrient increased, the length was reduced. Cu did not show any effect on leaf length when added with other nutrients. At the mid or late growth stages (after 60 days), the effect of Zn and B were prominent. Application of these two nutrients produced the longest leaf. When other nutrient added with Zn and B they reduced the length. Other nutrients such as Mo, Mn or Cu did not show any effect on length of the largest leaf of cauliflower.

2.4.2.2 Breadth of largest leaf

The breadth of largest leaf of cauliflower was significantly affected by micro-nutrient management (Table 2.4.6). At the early growth stages micro-nutrients were not able to show significant effect while at the late stage, the effect was clearly visible. After 30 days, the effect of micro-nutrients was insignificant although the application of Zn and B increased some leaf breadth. Some variation in leaf breadth was noted among the treatments. The highest breadth (19.68 cm) was recorded in treatment T_3 after 45 days, although it was statistically insignificant with T_1 and T_2. The lowest breadth was noted in T_0. There was no significant difference in treatment T_4, T_5 and T_6. The breadth of largest leaf was varied from 17.19 to 21.56 cm after 60 days. The widest leaf was recorded in T_3 while the narrowest in T_0. The treatments T_2, T_4 and T_5 were statistically identical. At the time of harvest, the widest leaf was obtained from T3 as before while the narrowest in T_0.

The results indicated that the effect of micro-nutrients at early stage was very negligible and it was clearly visible only after 45 days of transplanting. Zn, B and Mo showed positive effect on leaf breadth but when these nutrients were added with Cu or Mn reduced leaf breadth. After 60 days the highest dose of Zn, B and Mo resulted in best performance. However, Cu and Mn were not able to show any effect in leaf breadth in any growth period. The effect of Zn and B is considerable good in all growth period

Table 2.4.6: Breadth of largest leaf of cauliflower at different growth periods as affected by different micronutrient management.

Treatments	Breadth of largest leaf (cm) at			
	30 DAT	45 DAT	60 DAT	Harvest
T_0 =control	15.17a	15.88c	17.19e	17.41e
T_1=Zn_2B_2	16.06a	19.20a	21.09ab	21.3ab
T_2= $Zn_2B_2Mo_{0.5}$	15.22a	19.14a	19.14cd	19.35cd
T_3= $Zn_3B_3Mo_1$	13.88a	19.68a	21.56a	21.77a
T_4= $Zn_2B_2Mo_{.5}Mn_4$	15.69a	18.04ab	20.18bc	20.40bc
T_5= $Zn_2B_2Cu_1Mo_{0.5}Mn_4$	15.06a	18.16ab	19.08cd	19.30cd
T_6= $Zn_3B_3Cu_2Mo_1Mn_8$	15.11a	16.84bc	17.97de	18.19de
LSD (0.05)	2.326	1.564	1.288	1.288
CV (%)	8.62	4.85	3.72	3.68

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

2.4.2.3 Foliage coverage

Foliage coverage or canopy diameter of cauliflower plant was influenced by micro-nutrients used in this investigation (Fig. 2.4.7 and Appendix 16). After 30 days, the highest coverage (50.93 cm) was recorded in T_4 while the lowest coverage (38.73 cm) was noted in T_0. The treatments T_1, T_3 and T_5 were statistically identical.

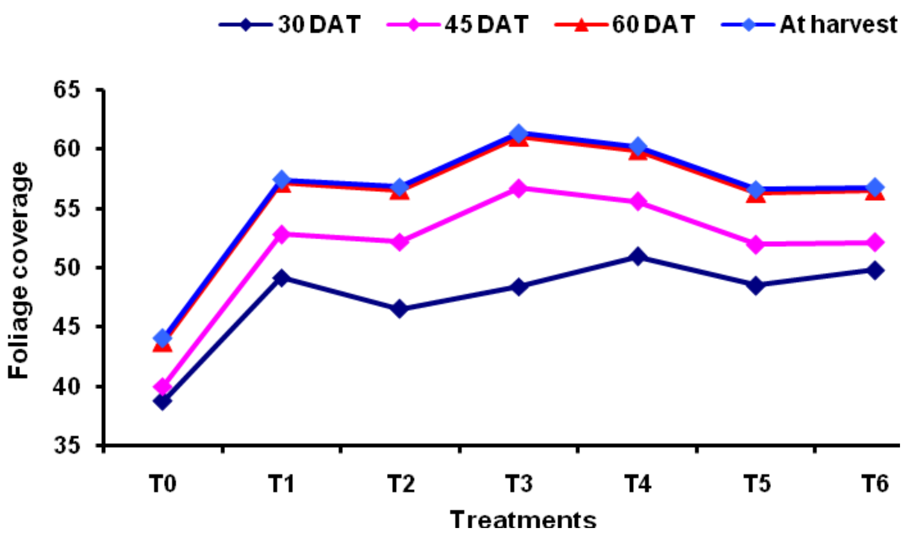

Figure 2.4.7: Foliage coverage of cauliflower plant at different growth periods as affected by different micro-nutrient management.

The highest coverage (56.67 cm) after 45 days was monitored in T_3 although it was statistically similar with T_4. The lowest coverage (39.98 cm) was noted in control plots.

The treatments T_1, T_2, T_5 and T_6 were insignificant among themselves. The foliage coverage at 60 days of transplanting showed similar trend as observed that of 45 days. At the time of harvest the highest coverage was recorded in T_3 while the lowest in T_0 as before.

The results showed that Zn and B sharply increased foliar coverage as compared with control plots. Higher doses of Zn and B and medium dose of Mo caused the highest coverage in all growth period except 30 days. When Mn was added with these nutrients it slightly reduced the coverage except 30 days. However, the nutrient Cu either used as lower or higher dose with other nutrients did not increased coverage rather decreased it.

2.4.2.4 Plant height

Micro-nutrients used in this investigation had significant effect on the height of the cauliflower plant (Fig. 2.4.8 and Appendix 17). The rate of increasing plant height was very slow up to 45 days then increased rapidly after which it became slow again up to the time of harvest. After 30 days, the tallest plant was recorded in T_4 which was statistically similar with T_2, T_3 and T_6. The shortest plant was noted in the treatment T_0. Similar trend in plant growth was monitored at 45 days. After 60 days, the tallest plant (42.25 cm) was obtained from the treatment T_5 although it was statistically similar with T_1, T_3, T_4 and T_6. The shortest plant at this growth period was noted in T_0. The tallest plant at the time of harvest was obtained from T_5 while the shortest in T_0. The height of the plant in treatments T_1, T_3, T_4 and T_6 was statistically identical. The tallest plant (43.93 cm) at the time of harvest was obtained in treatment T_5 followed by T_3, T_4 and T_6. Control plot always produced the shortest plant.

The results indicated that Zn and B sharply increased the height of cauliflower plant when added to the NPK nutrients in all growth period monitored. When Mo added with these two nutrients plant growth slightly increased at early stage but slightly reduced at late stage although this increase or decrease was insignificant. Prasad and Singh (1988) obtained the taller plant by the application of boron. It was observed that the lower doses of all micro-nutrients increased the plant growth while the higher doses reduced it. The results revealed that all the micronutrients contributed on plant height but higher doses are not suitable.

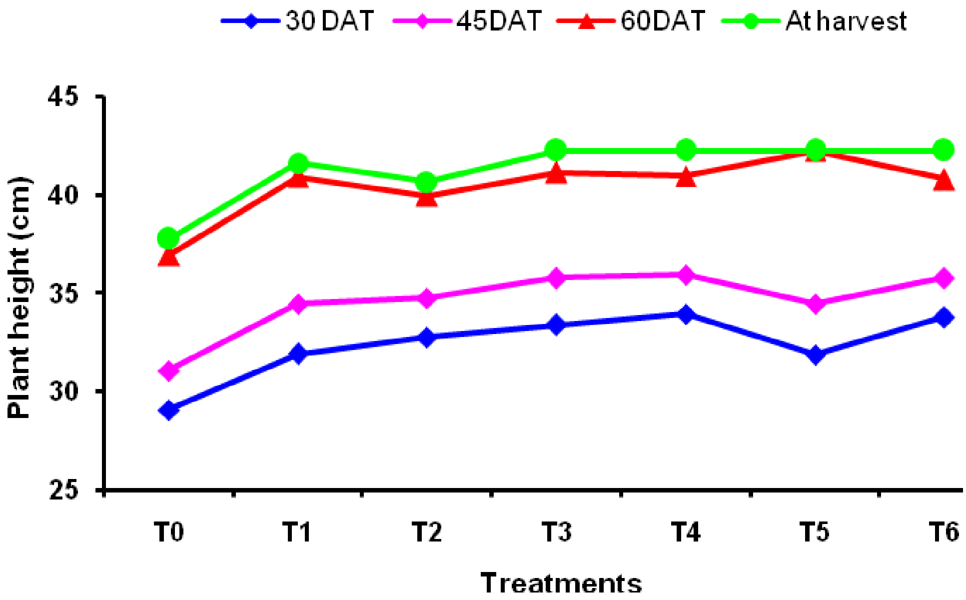

Figure 2.4.8: Height of cauliflower plant at different growth periods as affected by different micro-nutrient management.

2.4.2.5 Yield contributing characters

Yield contributing characters are shown in Table 2.4.7 and 2.4.8. It was observed that these parameters were significantly affected by the micro-nutrient management.

2.4.2.5.1 Curd diameter

The highest curd diameter (16.61 cm) was recorded in T_2 although it was statistically similar with T_1, T_3 and T_6. The lowest diameter was recorded in T_0 which statistically similar with T_5. However, it is very difficult to conclude the effect of micro-nutrients on curd diameter.

2.4.2.5.2 Curd thickness

The curd thickness was ranged from 8.95 to 9.95 cm. The thickest curd was recorded in T_2 while the lowest in $T_{0.}$ T_0 was statistically similar with the treatments T_0, T_3, T_4. $T_{5,}$ and T_6. The results indicated that the effect of Zn, B and Mo at 2, 2, 0.5 kg/ha dose was prominent on curd thickness although when these nutrients were added with Cu and Mn did not able to increase curd thickness.

Table 2.4.7: Diameter, thickness, curd weight and marketable curd weight of cauliflower as affected by different micro-nutrient management.

Treatments	Curd diameter (cm)	Curd thickness (cm)	Wt. of marketable Curd (g/plant)	Wt. of Curd (g/plant)
T_0 (control)	14.36c	8.95c	711.1c	522.2d
$T_1=Zn_2B_2$	16.47a	9.75ab	844.4ab	625.6abc
$T_2= Zn_2B_2Mo_{0.5}$	16.61a	9.95a	886.7a	707.8a
$T_3= Zn_3B_3Mo_1$	16.30a	9.01bc	862.2a	678.9ab
$T_4= Zn_2B_2Mo_{.5}Mn_4$	15.25bc	9.41abc	814.7ab	667.8ab
$T_5= Zn_2B_2Cu_1Mo_{0.5}Mn_4$	14.99c	8.75c	796.7abc	600.0bcd
$T_6= Zn_3B_3Cu_2Mo_1Mn_8$	16.13ab	9.21abc	766.7bc	569.4cd
LSD (0.05)	0.9346	0.6981	85.68	83.57
CV (%)	3.34	4.22	5.93	7.52

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

2.4.2.5.3 Marketable curd weight

The maximum marketable curd was produced by the treatment T_2 although it was insignificantly differed with T_1, T_3, T_4 and T_5. The results indicated that the lower doses of Zn, B and Mo showed increased marketable curd while higher dose of these nutrients or Cu and Mn were not able to increase marketable curd weight rather they reduced it.

2.4.5.4 Curd weight

The curd weight was varied from 522.2 to 707.8 g per plant with the highest weight in T_2 although it was statistically insignificant with T_1, T_3 and T_4. The lowest weight was noted in control plots (T_0). It was observed that Zn, B and Mo at lower dose showed positive effect on curd development as these nutrients significantly increased curd weight while Cu and Mn showed negative effect. The results agree with the finding of Sanjoy *et al*., (2002). They observed that boron application significantly increased curd diameter, curd weight and yield of cauliflower. Similar results also reported by Ghosh and Hasan (1997) and Mehrotra *et al*. (1975).

2.4.5.5 Leaf weight

The production of cauliflower leaves was significantly affected by micro-nutrients (Table 2.4.8). The maximum leaf (558.3 g) was produced by T_3 and it statistically similar with

T_1, T_2 and T_4. The minimum leaf (428.9 g) was produced by T_6 although it was statistically identical with T_0 and T_5. The results showed that Zn, B, Mo and Mn increased the leaf weight while the application of Cu reduced it.

2.4.5.6 Stem weight

Stem weight of cauliflower plant was significantly influenced by the application of micro-nutrients (Table 2.4.8). The maximum stem (87.78 g/plant) was produced by T_1 while minimum (56.67 g) by T_2. Stem weight of the treatments T_0, T_5 and T_6 were statistically similar. The results indicated that increased of stem weight of cauliflower by application of Zn and B was prominent. When Mo, Mn or Cu added to these nutrients it reduced the stem and finally higher doses of all the micronutrients slightly increased stem development although it was insignificant.

Table 2.4.8: Weight of leaf, stem and root of cauliflower as affected by different micro-nutrient management

Treatments	Leaf wt. (g/plant)	Stem wt. (g/plant)	Root wt (g/plant)
T_0 (control)	438.30b	70.00bc	23.20 a
T_1=Zn_2B_2	513.32 a	87.78a	21.54 a
T_2= $Zn_2B_2Mo_{0.5}$	521.81a	56.67d	21.52 a
T_3= $Zn_3B_3Mo_1$	558.30a	76.67b	24.10 a
T_4= $Zn_2B_2Mo_{.5}Mn_4$	515.33a	65.00 cd	23.15 a
T_5= $Zn_2B_2Cu_1Mo_{0.5}Mn_4$	461.7 b	66.11bcd	23.77a
T_6= $Zn_3B_3Cu_2Mo_1Mn_8$	428.92b	73.89 bc	20.53 a
LSD (0.05)	45.57	10.32	3.597
CV (%)	5.22	8.18	8.97

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

2.4.5.7 Root weight

The micro-nutrients used in this investigation were not able to show any significant effect on the development of root of cauliflower although the highest weight (24.10 g) was obtained from T_3 and the lowest (20.53 g) from T_6.

2.4.2.6 Yield

Micro-nutrients significantly affected the production of cauliflower (Table 2.4.9). The highest yield (35.82 tons, 24.67% increase over control) was obtained from T_2 which was statistically similar with T_1, T_3, T_4 and T_5. The lowest yield (28.73 t) was monitored in T_0.

The effect of Zn and B was clearly indicated with 18.76% increasing yield over the control. The addition of Mo at higher dose also increased the yield, although the increase was statistically insignificant. The nutrients Mn or Cu were not able to increase rather they reduced the yield. The results obtained in this study agree with Singh and Kapoor (2002); Farage *et al*., (1994); Adhikary *et al*., (2004); Batal *et al.* (1997); Varghese and Duraisami (2005); Bajwa and Sharma (1990); Sanjoy *et al*., (2002) and Prasad and Singh (1988). All of the investigators recorded the higher yield of cauliflower using different level of boron.

Table 2.4.9: Yield of cauliflower as affected by different micro-nutrient management.

Treatments	Gross yeild (t/ha)	Marketable curd yield (t/ha)	Increased yield over control (%)
T_0 (control)	50.21d	28.73c	-
$T_1=Zn_2B_2$	59.27a	34.1ab	18.76
$T_2= Zn_2B_2Mo_{0.5}$	60.07a	35.82a	24.67
$T_3= Zn_3B_3Mo_1$	61.47a	34.84a	21.26
$T_4= Zn_2B_2Mo_{.5}Mn_4$	57.30ab	32.91ab	14.54
$T_5= Zn_2B_2Cu_1Mo_{0.5}Mn_4$	54.47bc	32.19abc	12.04
$T_6= Zn_3B_3Cu_2Mo_1Mn_8$	52.12cd	30.98bc	7.83
LSD (0.05)	3.904	3.463	
CV	8.462	6.253	

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

2.4.2.7 Gross yield

Gross yield of cauliflower was significantly affected by micro-nutrients. It was varied from 50.21 to 61.47 t/ha (Table 2.4.9). The highest gross yield was recorded in the treatment T_3 while the lowest in T_0. The treatments T_1, T_2 and T_4 were insignificant. The results revealed that the nutrients Zn, B and Mo had positive response while Cu and Mn had negative response on gross yield.

Summary and Conclusion

Experiment 1

The results indicated that the leaf production increased significantly with the higher number of nutrient combinations only up to the middle stage of plant growth but minimal at maturity stage. When the micronutrients added individually or in a combination with NPK increased number of leaves but there were no significant difference with N, NP or NPK treatments. So it can be stated that micronutrient had no significant effect on leaf production at the growth stages compared with NPK fertilizers. At harvest maximum number of leaves (23.0) was found in NPKMo while minimum was in control (19.55).

The nutrients showed positive response on the leaf size. The treatment which received all nutrients always produced widest leaf in all growth stages monitored. The nutrients S, Zn and B increased the breadth of the leaf when added individually with NPK fertilizers. The results revealed that these micronutrients had positive insignificant effect on leaf size of cauliflower.

The combination of nutrients produced higher canopy diameter. At harvest the highest canopy 65.45 cm was in NPKSZnBMo while the lowest 42.65 cm was in the control. The results showed that all the micronutrients such as S, Zn, B and Mo increased the canopy diameter (59.57, 58.85, 60.58 and 58.28 cm respectively) when added individually with NPK (57.32 cm) fertilizers but the increase was more prominent in case of Boron. The result indicated that B plays important role in canopy development.

The nutrients S, Zn and Mo did not increase rather decreased (38.11, 35.77 and 40.87 cm respectively) the height of cauliflower plant at final growth stage when they added individually with NPK (40.94 cm). The results showed that application of boron individually or in combination with other fertilizers had significant and positive effect on plant height.

The heaviest leaves (710.07 g/plant), largest diameter of curd (16.26 cm) and maximum height of curd (9.73 cm) was found from T_6 (NPKB). The results showed that B had significant positive impact on the leaf weight, diameter of curd and curd height. S and Zn reduced the weight of loose leaves when added individually with NPK. Curd diameter and height was increased by B and Mo and decreased by S and Zn when added individually with NPK.

All yield parameters increased sharply with the application of B. The heaviest curd (499.78 g/ plant), marketable curd (715.30 g/plant) and highest yield (28.9 t/ha) was obtained from NPKB. Addition of nitrogen produced 261.21% higher yield over control. The result showed that when B is added with NPK yield increased 30.83% and Mo increases 17.11% whereas S and Zn decrease 19.92% and 7.92% respectively. Boron showed positive and significant influence on the yield of cauliflower.

The heaviest root (36.67g/plant) was obtained from NPKB which was statistically identical with T_7 and T_{10}. The heaviest stem (65.56g) and the highest gross yield (14.90 g/plant) as well as the highest increase over control (378.22%) were recorded in NPKB. The results showed that B increased root weight, stem weight and gross yield significantly but S and Zn reduced the gross yield of cauliflower at harvest (1021.22 and 1079.1 g/plant respectively) when added individually with NPK (gross yield 1222.51 g/plant). S reduced the stem weight also when added individually with NPK. The gross yield was slightly increased by Mo when added with NPK but it was insignificant.

Experiment 2

Manganese produced the longest leaf only at the early stage while increase dose of Manganese or other nutrient reduced it. The effect of Zn and B were prominent only after 60 days. Application of these two nutrients produced the longest leaf. When other nutrient added with Zn and B they reduced the length. The nutrients Mo, Mn or Cu did not show any effect on length of the leaf of cauliflower.

The effect of micronutrients on leaf wideness was very negligible at the early stage. Zn, B and Mo showed positive effect on leaf breadth but when these nutrients were added with Cu or Mn reduced leaf breadth. After 60 days the highest dose of Zn, B and Mo resulted in best performance. However, Cu and Mn were not able to show any effect in leaf breadth in any growth period. The effect of Zn and B is considerable good in all growth period.

The results showed that Zn and B sharply increased foliage coverage compared with control plots. Higher doses of Zn and B and medium dose of Mo caused the highest coverage in all growth period except 30 days. When Mn was added with these nutrients it slightly reduced the coverage area except 30 days. However, the nutrient Cu either used as lower or higher dose with other nutrients did not increase coverage rather decreased it.

The nutrients Zn and B sharply increased the height of cauliflower plant in all growth period monitored. When Mo added with these two nutrients plant growth slightly increased at early stage but slightly reduced at late stage although this increase or decrease was insignificant. The results revealed that the combination of micronutrients increased the plant growth.

Curd thickness and diameter was significantly enhanced by Zn, B and Mo at a dose of 2, 2, and 0.5 kg/ha but when these nutrients were added with Cu and Mn did not able to increase these parameters. Maximum curd Diameter (16.61 cm) and thickness (9.95 cm) were found in $Zn_2B_2Mo_{0.5}$ treatment.

The lower doses of Zn, B and Mo showed increased marketable curd while higher dose of these nutrients or Cu and Mn were not able to increase marketable curd weight rather they reduced it. It was observed that Zn, B and Mo showed positive effect on curd development as these nutrients significantly increased curd weight while Cu and Mn showed negative effect. The highest marketable curd weight 886.7 g/plant and highest curd weight 707.8 g/plant was in $Zn_2B_2Mo_{0.5}$ treatment.

The maximum leaf was produced by Zn, B and Mo. The results showed that Zn, B, Mo and Mn increased the leaf weight while the application of Cu reduced it. Stem weight of cauliflower was significantly influenced by Zn and B. When Mo, Mn or Cu added to these nutrients it reduced the stem and finally higher doses of all the micronutrients slightly increased stem development although it was insignificant. The micronutrients used in this investigation were not able to show any significant effect on the development of root of cauliflower.

The highest yield (35.82 tons, 24.67% increase over control) was obtained from treatment having $Zn_2B_2Mo_{0.5}$. The effect of Zn and B was clearly indicated with 18.76% increasing yield over the control. The addition of Mo at higher dose also increased the yield, although the increase was statistically insignificant. The nutrients Mn or Cu were not able to increase rather they reduced the yield. The results indicated that the rate of Zn (2 kg/ha), B (2 kg/ha) and Mo (0.5 kg/ha) is suitable for maximum curd yield, while Cu and Mn had no or negative effects on growth and yield of cauliflower. It is noted that Zn (3 kg/ha), B (3 kg/ha) and Mo (1 kg/ha) rates are not required in the experimental plots but it may be suitable in other regions of Bangladesh.

From the above two experiments it is clear that the rate of Zn (2 kg/ha), B (2 kg/ha) and Mo (0.5 kg/ha) along with the basal dose (N = 150, P = 50 and K = 100 kg/ha) is the most suitable dose for maximum curd yield in the experimental plots. Moreover, Cu and Mn or higher dose of Zn, B and Mo should not be applied here.

Chapter 3: Carrot

Experiment 1

EFFECT OF NUTRIENT MANAGEMENT ON GROWTH, YIELD AND YIELD COMPONENTS OF CARROT IN CALCAREOUS SOILS OF BANGLADESH

Experiment 2

EFFECT OF MICRONUTRIENT MANAGEMENT ON GROWTH, YIELD AND YIELD COMPONENTS OF CARROT IN CALCAREOUS SOILS OF BANGLADESH

Introduction

Carrot *(Daucus carota* L.) is an important vegetable crop. It belongs to the family Apiaceae (previously Umbelliferae) and is considered to be a native of Mediterranean region (Shinohara, 1984). It is a cold season crop and is grown all over the world; in spring, summer and autumn in temperate countries and during winter in tropical and subtropical climate (Bose and Som, 1990). According to Barnes (1936)**,** 15.6 to 21.1°C temperature is the best for its growth and development. In Bangladesh it is grown during the winter season when temperature ranges from 11.7 to 28.9°C (Alim, 1974).

Carrot is a delicious and highly nutritious root crop. It is rich in carotene, thiamine and riboflavin and it is an excellent source of iron, vitamin A, vitamin B, vitamin C and sugar (Yawalkar, 1985). Vitamin-A deficiency is wide spread among the children of Bangladesh. Here, about 35,000 children are becoming blind every year due to deficiency of vitamin-A in their daily diet (Chandra, 1992). This deficiency of vitamin-A could be corrected to a great extent by growing and eating more carrots. In the year 2007-08 the area under carrot cultivation was 1,154 hectare with total production of 10,430 metric tons (BBS, 2009).

The yield of carrot in Bangladesh is very poor. In the year 2007-08, it was 9.39 t/ha (BBS, 2009) which is very low compared to other developed countries like, UK (66.66t/ha), Sweden (46.59 t/ha), Austria (55.84 t/ha), Switzerland (53.33 t/ha), Kuwait (51.19 t/ha) and Israil (52.00 t/ha) (FAO, 2003). Improper production practices such as use of imbalance fertilizers and suboptimal irrigation adopted by the growers are the major reasons for poor yield of vegetables (Naher *et al*., 2007).

Production of carrot could be increased in two ways, either by extending the area for the cultivation or by increasing the yield per unit area. But due to limitation of land it is not possible to raise the production of the crop horizontally. So, the only way to increase the production through increasing yields per unit area. This can be done in many ways, of which the most important one is the judicious application of different fertilizers. Bangladesh has been reported to be deficient in some macro and micronutrients, namely, Zn, B, Mg and Mn. It has been suggested by Karim *et al*. (1992) that the yield of tuber crops like potato can be increased by 5-15% through applying Zn.

In carrot cultivation, NPK fertilizer is essential. Nitrogen is necessary for its growth and developments particularly in early stages which leads thicker and healthy root development (Karl *et al.,* 1950; Thompson and Kelly, 1957). Phosphorus and potassium are also necessary for root development. All root crops respond to liberal applications of potassium. Potassium is essential for photosynthesis and for starch formation and the translocation of sugars (Buckman and Brady, 1983). Phosphorus and potassium fertilizers are also necessary for quality of carrot (Dyachenko and Kurumli, 1978).

Many workers have pointed out the vital role different fertilizer management (N, P, K, S, Zn, B, Mn and Mo) on the yield of carrot (Balooch *et al*. 1993; Haaz and Homa, 1969; Homutescu *et al.* 1963). The requirements of B in vegetables are generally more than other crops (Rasp, 1985). Nitrogen manuring raised the carotene content and Potassium manuring increased the vitamin C content of carrots (Wo1f, 1955). Boron and Zn also stimulated carotenoid synthesis (Florescu and Cernea, 1961).

Necessary information regarding the use of different nutrient elements particularly S, Zn, B and Mo in combination with NPK for production of carrot under Bangladesh condition is scanty. Under the circumstances, the present study was undertaken with the aim to investigate the effect of nutrient management practices on the growth, yield and yield components of carrot. It is hoped that this type of new research will be very helpful for the researchers and vegetables growers. Considering these facts, the present study was conducted with the following objectives:

i. To evaluate the effect of macro-nutrients (N, P and K) and micro-nutrients (S, Zn, B, Cu, Mn and Mo) on the growth and yield of carrot;

ii. To compare the response of micro-nutrient with macro-nutrient on the growth and yield of carrot; and

iii. To find out the optimum doses of fertilizers for maximizing yield potentiality of carrot.

Review of Literature

Carrot (*Daucus carota L.*) is one of the most important vegetable crops and received much attention to the researchers throughout the world to develop its production techniques. Many research works have been carried out in relation to macro and micro nutrient fertilizer application of carrot in different countries. However, few studies have been carried out in this aspect in Bangladesh. A brief review of these works in relation to the effect of different macro- and micro- nutrients on growth, yield and quality of carrot are presented in this chapter.

3.2.1 Effect of Nitrogen, Phosphorus and Potassium

Karl *et al.* (1950) and **Thompson and Kelly (1957)** described that nitrogen is mainly responsible for promoting the growth of carrot. Carrot is considered to be heavy nitrogen feeders, particularly in the early stages of their growth for a good foliage formation which later leads to healthier and thicker root development. Phosphorus is also considered to be a pre-requisite soil constituent for all root crops. It has been associated with the development of roots and early maturity of crops. Potassium is necessary in plant for carbohydrate synthesis and their translocation. Thus, higher quantity of potassium is needed for root crops cultivation.

A moderate amount of nitrogen was found necessary to give maximum yield of carrot and excess of nitrogen tended to increase root splitting. On the other hand adequate phosphorus was necessary for maximum yield, whereas, potassium had little effect on the yield of carrot **(Goodman, 1953).** In a trial with three levels of phosphorus and two levels of potassium to Chantenay carrots, yield was increased at both levels of phosphorus **(Lamm and Hintze, 1958).** There was positive interaction between phosphorus and potassium in phosphorus deficient soil.

A strong response of nitrogen fertilization was observed by **Burleson (1957**) in carrot grown on a loamy soil in the lower Rio-Grande valley. He reported that 40 lbs nitrogen per acre gave maximum production of carrot roots while phosphorus and potassium had no influence on the yield. A trial in India by **Deshi *et al*. (1964)** found that the application of P_20_5 -28 kg, N - 28, 56 or 84 kg and K - 28 or 56 kg per hectare significantly increased the leaf number and height of plants and improved root length and root diameter of carrot. A combination of 56 kg nitrogen and 56 kg potassium per hectare gave the highest yield of carrots in sandy loam soils.

Verma and Bajpai (1965) have determined the effect of 3 levels of nitrogen and 4 levels of phosphorus and combinations of these treatments on the yield of carrot. He concluded that phosphorus had no significant effect on the yield of either root or foliage, whereas nitrogen increased the yields in both the years.

Giarini and Pimpini (1966) studied the effects of phosphorus and potash on the yield of carrot. In the richer soil the yield of marketable carrot was increased considerably by nitrogen and slightly by phosphorus while it was unchanged by potash. Leaf colour, growth, root yield and quality were greatly improved by nitrogen but phosphorus produced only a slight yield response. However, potash had a little effect except enhancing the action of mineral nitrogen on yield. In presence of phosphorus and potash the optimal dose of nitrogen was higher than when applied alone. **Garner (1967)** observed that nitrogen application reduced the number of marketable carrot root while potassium increased it.

A trial by **Basso (1968)** reported that the response of nitrogen was higher than phosphorus and the highest increase (62%) in root production was obtained when 160 kg N was applied with 240 kg P_20_5 in carrots cv. Nantes.

Green (1973) reported that the application of 100 kg N per hectare was beneficial, whereas the response to P was not consistent and potash had no response at all under the soil condition of northern Nigeria. **Habben (1973)** observed that raising the N level increased top growth than root growth. Potassium fertilization did not affect top growth while root growth was reduced as the K level was raised. High nitrogen levels promoted carotene formation but potassium had little effect on carotene synthesis. **Starikov (1973)** investigated the effect of fertilizers and soil types on the formation of carrot roots. He observed that phosphorus stimulated the growth and restricted growth in length.

Otani (1974) reported that the height of carrot plant, leaf number as well as fresh weight of roots and tops was increased with the increase of nitrogen. He noted a varietals' difference in response of fertilizer application. Moderate amount of nitrogen (100 lbs per acre) increased the root yield of carrot significantly while potash did not show any significant effect **(Sein, 1975).**

A close correlation between carrot yield and leaf phosphorus content was reported by **Pankov (1976).** Optimal leaf phosphorus content in relation to plant growth and yield was determined to be 0.25-0.26%. Phosphorus deficiency reduced yields but increased dry matter, sugar and carotene contents.

Burdine and Hall (1977) studied the responses of fertilizers on organic soils. He found that response to phosphorus was significant with optimum yields at 88 lb/acre while the response to potassium was not significant.

Dyachenko and Kurumli (1978) showed that phosphorus and potassium fertilizers increased the yield, quality and resistance to storage root of carrot. However, nitrogen and potassium fertilizers doubled the storage losses and lowered carrot resistance to roots.

Hipp (1978) reported that **a**pplication of nitrogen at 56 or 112 kg per hectare increased the yield of carrot while higher dose (168 kg) did not improve the yield over 112 kg per hectare.

Solovev and Lapushkina (1978) reported that nitrogen had the highest effect on carrot yield and vitamin accumulation. Phosphorus and potash had no appreciable effect on accumulation of vitamin C, carotene, thiamine and riboflavin.

Polack (1982) applied nitrogen at the rate of 0-180 kg and potash at the rate of 0-196 kg per hectare to carrot. A basal dose of nitrogen at 60 kg and potash at 151.2 kg, respectively gave the best yields and quality of carrot. Nitrogen did not impair the storability. However, potash showed variable effects on the storability of carrot.

Farazi (1983) obtained the highest yield of carrot (45.5 t/ha) from the highest dose of nitrogen (112 kg N/ha). On the other hand potash had no significant effect on the yield. Both nitrogen and potash had significant effect on the root diameter but little effect on the length of root. Weight of leaves was increased with the creasing level of nitrogen while potash had no considerable effect on it.

The effect of N, P and K fertilizers on carrot yield was studied by **Krarup *et al.*, (1984).** He did not find any differences in yield with the medium and high levels of N, P, K but the highest level of P resulted in lower yields of first class roots.

Michalik (1985) have determined the effect of fertilizers on dry matter, sugar and carotene content of carrot cv. *Nantes*. Nitrogen as ammonium nitrate or urea had no significant effect on dry matter. Phosphorus as triple super phosphate had no significant effect on dry matter while potassium in chloride or sulphate form did not affect dry matter.

Salmman (1985) studied the effect of spacing and potassium fertilization on growth and yield of carrot (*Daucus carota* L.) in Iraq. He noted that reducing the plant spacing as well as the application of potassium fertilizer significantly increased total tops and root yield. He observed that the reduction in plant spacing caused a significant reduction in top fresh and dry weight per plant as well as average root size while the application of potassium fertilizer increased them.

Wiebe (1987) studied the effects of plant density and nitrogen supply on yield, harvest date and quality of carrot. Plants were grown at densities ranging from 350 to 1200 plants/m^2 and nitrogen was applied at 80-200 kg/ha. It was observed that 600-700 plants/m^2 gave higher yield of marketable roots for late harvest. The response to nitrogen fertilization varied, with 80-140 kg N/ha generally gave the most satisfactory results.

Skrbic (1987a) obtained an average yield of 85 tons per hectare of carrot in cv. *Scarlet Nantes* and *Formula*. He commented that the yield depended on the quantity of nitrogen fertilizer and it was the highest when 30 kg of nitrogen per unit area was used. There was practically no difference between the varieties.

The influence of nitrogen on the growth and nitrogen content in roots and leaves was studied by **Skrbic (1987b).** He monitored slow growth of carrot at the beginning of the vegetation period and quite intensive growth after the formation of 7-8 leaves until maturity is reached. Nitrogen increased the weight and number of leaves. Nitrogen content in roots and leaves decreases during the vegetation period and it is the highest at the beginning and lowest at the maturity. At the beginning of the vegetation period, carrots have the greatest need for nitrogen.

Orphanos and Krentos (1988) tested combinations of 4 rates of nitrogen and phosphorus. He obtained increased yield with 63 to 126 kg nitrogen per hectare. The increased in yield due to nitrogen application was accompanied by an increase in exportable yield but at the highest nitrogen rate (189 kg N/ha) exportable yield declined slightly. The dry matter content and the N, P and K contents of the root were not influenced by either N or P was around 70 tons/ha.

Sarker (1989) obtained the highest yield of 31.99 ton per hectare of carrot from the plants fertilized with the highest dose of nitrogen (120 kg N/ha). The interaction of N x K significantly affected the yield of carrot but had no significant effect on root length, root diameter and dry weight of root. The highest yield of 34.27 ton per hectare was recorded when nitrogen and potash each at 120 kg per hectare was applied. Applications of nitrogen significantly affect the root length and individual root weight and had no significant effects on root diameter and root dry weight. Potassium had significant effect on root diameter and root fresh weight and had no significant effects on root length.

The effect of NPK on yield and quality of carrot was investigated by **Almazov and Kholuyak (1990).** NPK gave the highest yield and increased carotene contents in carrot root. **Balooch *et al.* (1993)** grown carrots from seed which 75 or 100 kg P_20_5 and 75, 100 or 125 kg K_20/ha had been applied. All plots also received 100 kg N in 3 installments during seed bed preparation. They obtained served highest root yield (29.79 t/ha) at the highest NPK rate.

3.2.2 Effect of Boron

Kelly *et al*. (1952) conducted a research on to find out the effect of boron on the growth and carotene content in carrots**.** Carrot was grown in sand culture both in a green-house and in the open field with boron at the rate of 0.0, 0.1, 0.5, 2.0 and 5.0 ppm. Boron deficiency symptoms developed in control plots while toxicity symptoms with 5.0 ppm.

The highest top yield was obtained from 0.5 ppm while the highest root yield was obtained from 2.0 ppm boron.

Kononovich (1971) reported that carrot seeds soaked in solutions of 0.1% boric acid at 1.6 litre/4 kg seeds, showed 63% germination, compared to 42% in the control. The treatments also increased yield, carbohydrate and vitamin - C contents.

The sensitivity of carrot to boron under different levels of nitrogen was determined by **Nelyubova *et al.* (1972).** He obtained the highest yield when boron was applied with a basal dose of NPK (30:60:90 kg/ha). He noted that the yield did not increase when nitrogen was raised to 60 or 120 kg/ha. **Alekseeva and Rasskazov (1976)** reported that boron increased the total yield by 6.2-13.2% and the commercial yield by up to 6.3% carrot. Increases in sugar, carotene and dry matter contents were also noted. **Szmidt (1980)** reported that soil Boron content above 1.5-2.0 mg or below 0.5 mg per litre resulted in decrease in root yield of carrot cv. *Nantes*. The requirements of Boron in vegetables are generally more than other crops as observed by **Rasp (1985).**

Maurya and Singh (1985) reported that application of 10 kg borax/ha produced maximum height (55.15 cm.) in radish when the dose of borax was increased beyond 10 kg/ha, the height was decreased gradually.

3.2.3 Effect of Zinc

Dusting carrot seeds with zinc powder or soaking them in 0.05, 0.1 or 0.15% zinc sulphate raised the leaf chlorophyll content and increased the translocation of carotene from the leaves into the roots **(Tkacuk, 1967).**

Zinc sulphate (containing 23% Zn) at the rate of 0-200 kg/ha was applied in the first year and its effect in the following 5 years were studied by **Wisniewska (1980).** He reported that root yield of carrot was the highest in plot receiving no zinc and then decreased with increasing zinc rates in the year of application, and in the 3rd year after application; in the 5th year they were highest on plots which received zinc at 200 kg/ha.

Mathur *et a1.* (1989) studied the influence of zinc on the yield of carrot. The moisture, fertilization and temperature conditions provided were known to be non-limiting. It was found that correlations between yields per unit soil volume and soil properties, including soluble nutrients were generally not statistically significant.

3.2.4 Effect of different combination of nutrients

The response of carrots to various fertilizer treatments including N, P, K, lime, FYM and borax were studied by **Salonen (1961).** Carrots showed less or no response to the treatments while yield was increased by borax applications.

Forbes and Westgate (1963) studied various levels of N, P, K and Mg and noted that the yield of carrot due to N was highly significant. There was no response to addition of P from super phosphate. Magnesium significantly increased the yield. Best yield was obtained with the combination of 200 to 250 lbs of N, 200 lbs K_20 and 60 lbs of Mg per acre. There was no consistent difference between muriate and sulphate of potash as source of potassium.

The response of carrots to micronutrients was studied on an organic soil in Manitoba by **Campbell and Gusts (1966).** They reported that addition of Manganese, Zinc and Boron did not show a measurable response to carrot.

Kanwar and Malik (1970) observed that micro nutrient had no effects on root quality although boron increased the root yield when applied in combination with lower dose of NPK. **Kevorkov (1972)** reported that the effectiveness of the minor elements was greater in the unlimed soil. Yields of plants received Boron + Molybdenum (1 or 2 mg per kg soil) were higher than with either of the elements applied alone. The treatment increased the root carotene and carbohydrate contents.

An interaction between organic and mineral fertilization on carrot (cv. *Nantes*) was determined by **Luzzati *et al.* (1977).** He reported that organic manure did not increase the yield. The highest rate of P_20_5+K_20 (160 kg/ha each) increased the yield of roots irrespective of nitrogen.

Establishment and yield of carrot depended on an adequate supply of nitrogen, phosphorus, potassium and copper as reported by **Cole, (1984).** He further noted that phosphorus was necessary for carrot establishment while root formation was very poor in the absence of potassium.

A trial conducted by **Subhan (1988)** at 1250 m altitude with Grandasil D (containing 14% N, 12% P_20_5, 14% K_20 and 1% Mg) at the rate 0, 1, 2 or 3 g/litre as foliar spray to carrots. He obtained increased yield at 1 g/litre at 1-week interval application while he noted no additional effect at 2-weeks intervals. The highest yield was recorded at 3 g /litre.

Materials and Methods

Two experiments were conducted to investigate the effect of nutrient management on carrot yield in calcareous soils of Bangladesh. First experiment was done from November 2008 to March 2009 and second experiment was done from November 2009 to March 2010. This chapter describes the materials and methods of these experiments which include a short description of experimental site and soil, climate, planting materials, layout of treatments, manure and fertilizations, intercultural operations, weed and pest management, data collection, harvesting and statistical analysis. The details of these are described below.

3.3.1 Experimental site and soil

The investigation was conducted at the Horticulture Centre, DAE, Kallyanpur, Chapai Nawabganj. The soil of the experimental area was silty clay loam and belongs to the High Ganges River Floodplain, AEZ-11 (BARC-2005). The soil sample (0-15 cm) was collected and analyzed of soil texture by Hydrometer method and other parameters by Hunter (1984) from SRDI (Soil Resources Development Institute), Regional Lab, Shaympur, Rajshahi. The physico-chemical properties of the soil of the experimental plots are presented in Appendix 2.

3.3.2 Climate

The climate of the experimental site is subtropical in nature, which is characterized by three distinct seasons, the monsoon extending from May to October, the winter or dry season from November to February and pre-monsoon period hot season from March to April. The seasonal condition comprises of sufficient precipitation during the months from April to September and scant or no rainfall during the rest of the months of the year. Plenty of sunshine and moderate low temperature prevails during Rabi season from October to March which is suitable for growing Rabi vegetables in Bangladesh.

Information regarding monthly maximum and minimum temperature, rainfall, relative humidity, soil temperature as recorded by the Regional Horticulture Research Station, Chapi Nawabganj during the study period has been presented in Appendix 3a and 3b.

3.3.3 Land preparation

The selected land was opened on 3 November, 2008 for the first experiment and on 7 November 2009 for the second experiment with a power tiller and it was exposed to the sun for 7 days prior to next ploughing. It was prepared afterwards by ploughing and cross ploughing followed by laddering, broking large clods into pieces by hand tools, removing weeds and stubbles from the field. Finally, the land was leveled and the soil was taken into good tilth.

3.3.4 Treatments of Experiment

A total of 11 treatments including the untreated control were selected in experiment 1 while in experiment 2 include only 7 treatments. The experimental treatments were as follow:

Experiment 1

T_o = Control
T_1 = N
T_2 = NP
T_3 = NPK
T_4 = NPKS
T_5 = NPKZn
T_6 = NPKB
T_7 = NPKMo
T_8 = NPKSZn
T_9 = NPKSZnB
T_{10}= NPKSZnBMo

Experiment 2

T_0 = Control
T_1 = Zn_2B_2
T_2 = $Zn_2B_2Mo_{0.5}$
T_3 = $Zn_3B_3Mo_1$
T_4 = $Zn_2B_2Mo_{.5}Mn_4$
T_5 = $Zn_2B_2Cu_1Mo_{0.5}Mn_4$
T_6 = $Zn_3B_3Cu_2Mo_1Mn_8$

NB: 0.5, 1, 2, 3, 4 and 8 indicated Kg per hectare, where N_{150}, P_{50}, K_{100} were applied as basal dose

3.3.5 Design and layout of the experiment

The layout of both the experiments was randomized complete block design (RCBD) with three replications. A block consisted of 11 unit plots in experiment 1 and 7 unit plots in experiment 2. The size of a unit plot was 1.8 m × 1.65 m. The gap between the plots was

50cm and between the blocks was 100cm. The field layout was done on 12 November, 2008 in the first experiment and 16 November 2009 in the second experiment.

3.3.6 Planting materials

The seeds of carrot cv. New Kuroda a Japanese variety were used in the experiment. The seeds were produced and packed in sealed container by Takki and Co. Ltd., Kyoto, Japan and was collected from Haque seed store, Naodapara, Rajshahi.

3.3.7 Doses of nutrients and their methods of application

The doses and sources of the fertilizers were applied into the experimental 1 and 2 were as follow:

Table 3.3.1 Dose of different nutrients applied to the experiment 1.

Name of nutrient elements	Dose (kg/ha)	Source of fertilizer
N	150	Urea
P	50	TSP
K	100	MOP
S	20	Gypsum
Zn	3	Zinc oxide
B	3	Boric acid
Mo	1	Ammonium molybdate

Table 3.3.2 Dose of different nutrients applied to the experiment 2.

Treatment	Dose (kg/ha)				
	Zn	B	Mo	Cu	Mn
T_0 = Control	-	-	-	-	-
$T_1 = Zn_2B_2$	2	2	-	-	-
$T_2 = Zn_2B_2Mo_{0.5}$	2	2	0.5	-	-
$T_3 = Zn_3B_3Mo_1$	3	3	1	-	-
$T_4 = Zn_2B_2Mo_{.5}Mn_4$	2	2	0.5	-	4
$T_5 = Zn_2B_2Cu_1Mo_{0.5}Mn_4$	2	2	0.5	1	4
$T_6 = Zn_3B_3Cu_2Mo_1Mn_8$	3	3	1	2	8

As basal dose 150 kg N, 50 kg P_2O_5 and 100 kg K_2O were applied in experiment 2. The source of Mn was Manganese oxide and Cu from cupper sulphate. The whole amount of TSP, gypsum, zinc oxide, boric acid, ammonium molybdate, maganese oxide, cupper sulphate and 50% of urea and MP were applied at final plot preparation. Rest MP and urea were applied in two equal installments at 15 and 35 days after sowing of seeds followed by irrigation.

3.3.8 Sowing of seed

The seed were soaked in water for 24 hours and then wrapped with a piece of thin cloth. The seeds started to germinate after 24 hours of soaking. Seed was sown on 13 November 2008 in the first experiment and on 17 November 2009 at the rate of 3 kg/ha as recommended by Rashid (1993). Small holes of about 1.5 cm depth made at a distance of 10 cm along the row spaced at a distance of 25 cm and 3-4 seeds were placed in each hole.

3.3.9 Intercultural operations

3.3.9.1 Weeding and mulching

Weeding was done three times to keep the plots free from weeds and the soil was mulched by breaking the upper crust for easy aeration and to conserve soil moisture as and when needed.

3.3.9.2 Irrigation

Irrigation water was provided to the carrot field at 15, 35 and 55 days after sowing of seeds. In addition to that, about 45 mm rainfall was recorded during the crop period. However, each top-dressing was followed by irrigation. The irrigation was done carefully of each unit plots.

3.3.9.3 Gap filling

The experimental plots were monitored regularly to find out any damage or dead seedlings for replacement. Gap filling was done as and when required with the border plants.

3.3.9.4 Plant protection

Malathion 57 EC @ 2ml/L was sprayed to control the cutworm insects.

3.3.10 Harvest of crops

The carrot was harvested when the leaves become pale yellow in colour. The crop was harvested plot wise by hand carefully. The attached soil of carrot roots were cleaned properly.

3.3.11 Methods of data collection

To assess the effect of nutrient management on growth, yield and yield components of carrot, data on the following parameters were recorded from 10 sample plants during the course of experiment. The sampling was done randomly in each plot in such a way that the border effect could be avoided. The plants in the outer rows and at the extreme end of the middle rows were excluded to avoid the border effect. The following parameters were recorded in the present study.

3.3.11.1 Number of leaves

The total number of leaves or loose leaves per plant was counted from 10 selected plants of each plot and mean value was recorded periodically at 15 days interval.

3.3.11.2 Height of plant

The height of the sample plants was measured on the basis of average height of 10 plants in centimeter from the ground level to the tip of the largest leaf. Data were recorded at 45, 60, 75, 90 and 105 days after sowing of seed.

3.3.11.3 Fresh weight of loose leaves

Leaves were detached by sharp knife at the time of harvest and weight of loose leaves was expressed in gram.

3.3.11.4 Fresh weight of root

Leaves were detached from roots before taking weight of root at harvest. The weight of roots was measured in gram with an electrical balance.

3.3.11.5 Length and diameter of carrot root

The length of the root was measure in centimeter by a scale from the point of attachment of the leaves to the root up to the last point of the tapered end of the root. To measure the diameter of the root, a slide calipers was used. The diameter of the root was measured at upper, the middle and lower part of the root namely maximum, medium and minimum diameter and then means diameter was obtained.

3.3.11.6 Dry matter of leaves

Sample of two hundred gram chopped leave from sample plants was dried in air under laboratory condition. Air dried sample was then put in paper packets and oven dried for three days at 70°C till the weight was constant. The dry weight was recorded in gram and mean value was calculated. Percent dry matter was calculated by using the following formula:

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

3.3.11.7 Dry matter of root

Immediately after harvest roots were cleaned. Then 200g of roots were weighed and cut into small pieces and dried in the air under laboratory condition. Then it was dried in an oven at 70°C for three days till the weight was constant. After drying, it was weighed in an electrical balance. Percent dry matter was calculated by using the following formula:

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

3.3.11.8 Root yield

All leaves were removed from the plants and the weight of roots was taken from every unit plot separately for record. Then the yield per plot was converted into yield per hectare basis and was expressed in metric ton (t).

3.3.11.9 Cracked root

At harvest number of cracked carrot roots was counted and expressed in percentage.

3.3.11.10 Marketable root

It compromises of roots other than branched, cracked and rotten roots.

3.3.11.11 Non-marketable root

Branched, cracked and rotten carrot roots were counted.

3.3.12 Statistical analysis

The collected data on different parameters were analyzed statistically using MSTAT C Statistical package programme. The means for all the treatments were calculated and analyses of variances of all the characters studied were performed by F-test. The significance of the differences among the means were evaluated by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Results and Discussion

Two experiments were carried out to investigate the effect of nutrient management on the growth and yield of cauliflower. The findings of two experiments are presented under separate heads.

Experiment 1

Effect of nutrient management on growth, yield and yield components of carrot in calcareous soils of Bangladesh

3.4.1.1 Plant height

The nutrient elements either individually or in combinations showed significant effects on the height of carrot plant at different growth periods (Fig. 3.4.1 and Appendix 18). The plant height increased gradually with the passage of time and reached to its maximum at the time of harvest.

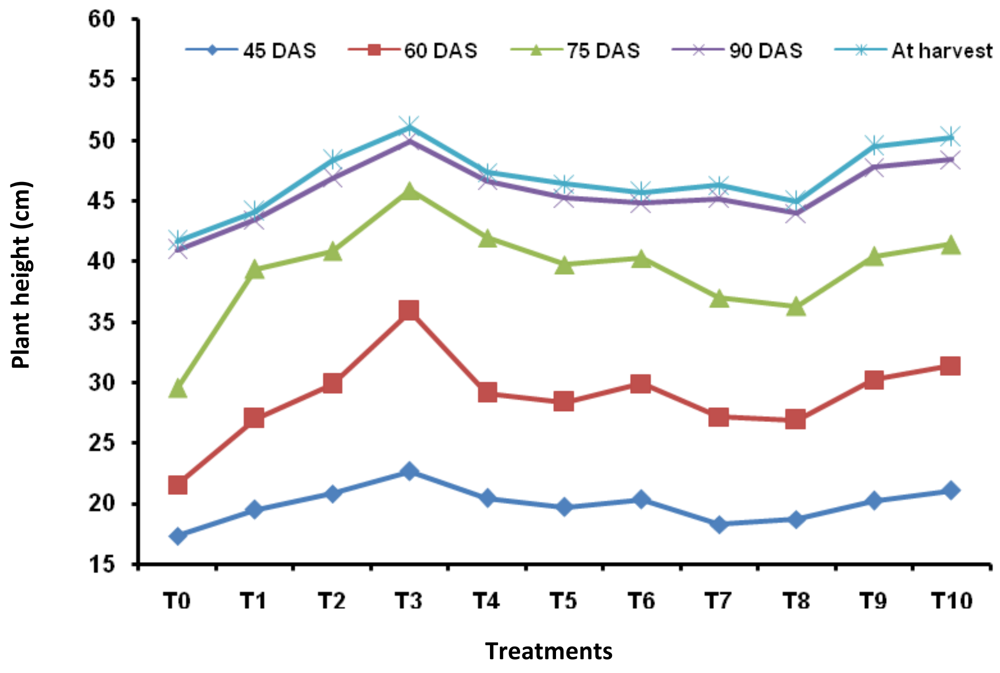

Figure 3.4.1: Height of carrot plant at five growth periods under different nutrients management

At 45 DAS, the height ranged from 17.31 to 22.66 cm. The maximum plant height was obtained in T_3 (NPK). The minimum 17.31 cm was recorded in control plots. Plant height in the treatments T_2, T_4, T_6, T_9 and T_{10} were statistically similar. The treatments T_1, T_2, T_4, T_5, T_6, and T_9 were statistically similar. The maximum plant height (35.85cm) after 60 days was found in T_3 followed by T_{10} (31.38 cm). The treatments T_2, T_4, T_6 and T_9 were statistically similar. The minimum plant height (21.54 cm) was recorded in control plot.

The height varied from 29.54 to 45.85 cm after 75 days. The maximum plant height (45.85 cm) was recorded in T_3 followed by T_4, T_{10}, T_2 and $T_{9.}$ The treatments T_2, T_4, T_9 and T_{10} were statically similar. The minimum plant height (29.54 cm) was recorded in control plots. The maximum plant height (49.90 cm) after 90 days was recorded in T_3 followed by T_{10}, T_9, T_2 and $T_{4.}$ The minimum plant height (40.93 cm) was recorded in control plots in this growth period. At harvest, the maximum plant height (51.08 cm) was recorded in T_3 while the minimum plant height (41.66 cm) in control plots.

The results showed that plant height increased gradually during the early stages of growth, rapidly between 60 to 90 days and then slowly at late stage. The result was in accordance with Skrbic (1987b) who noted slow growth of carrot at the beginning of vegetative period and quite intensive growth after the formation of 7-8 leaves until maturity.

The results indicated that NPK fertilizers had remarkable effect on height of carrot in all growth period monitored. The application of micronutrients (S, Zn, B or Mo) either individually or in combination to the NPK fertilizers always produced smaller plant. This revealed that micronutrients had no effect on the growth of carrot plant. Deshi *et al*. (1964) recorded significant increase in growth of carrot plants due to the application of NPK fertilizers.

3.4.1.2 Number of leaves

The production of leaves of carrot plant was significantly increased at different growth stages by the application of nutrients. Number of leaves increased gradually during the early stages of growth, rapidly between 60 to 90 days and later the plants produced small number of leaves (Table 3.4.3). The maximum number of leaves (15.38) was produced by the plants which received Zinc with NPK (T_5) although it was statistically similar with T_2, T_8, T_9 and T_{10} at time of harvest. The minimum leaves (11.16) were recorded in control plots. The results revealed that Phosphorus, Sulphur, Zinc, Boron or Molybdenum had no significant effect on the production of leaves in carrot. Skrbic (1987b) noted that nitrogen fertilization had significant effect on the dynamics of increase in number of leaves in carrot.

Table 3.4.3: Effect of nutrients on the production of leaves of carrot at five growth period as affected by different nutrient management.

Treatments	Number of leaf at				
	45 DAS	60 DAS	75 DAS	90 DAS	Harvest
T_0=Control	8.53a	8.99c	10.17d	10.50f	11.16e
T_1=N	9.20a	10.16ab	12.17bc	13.12de	13.79bcd
T_2=NP	8.73a	10.38ab	13.83a	14.59a	15.07abc
T_3=NPK	8.13a	9.47b	12.14bc	13.01de	13.51cd
T_4=NPKS	9.13a	10.73ab	12.07bcd	13.09de	14.05bcd
T_5=NPKZn	8.67a	10.07bc	13.42ab	14.37ab	15.38a
T_6=NPKB	9.67a	10.78a	12.60abc	13.45cde	14.04bcd
T_7=NPKMo	9.33a	10.01bc	11.70cd	12.37e	13.03d
T_8=NPKSZn	8.93a	10.29ab	13.62abc	14.15abc	15.15ab
T_9=NPKSZnB	8.27a	10.11ab	13.43abc	13.99bcd	14.66abcd
T_{10}=NPKSZnBMo	9.00a	10.27ab	12.02bcd	13.05de	14.17abcd
LSD ($P \geq 0.05$)	1.840	1.226	1.765	1.026	1.464
CV (%)	13.56	6.71	8.26	4.51	6.12

In a column, figures having same letters do not differ significantly by DMRT at 5% level

The results of the present experiment agree with the findings of Deshi *et al.* (1964) who reported significant effect of NK on leaf production in carrot. Green (1973) also reported that application of Nitrogen was beneficial, the response to Phosphorus was not consistent and there was no response of Potassium or trace elements in carrot. It might be due to the increase in number of leaves as a result of more efficient photosynthesis in the plants resulting in higher root yield of carrot.

3.4.1.3 Root length

A significant difference was noted in length of carrot root at harvest due to nutrient management (Fig. 3.4.2 and Appendix 19). The length of the root ranged from 14.18 to 16.22 cm. Application of NPK (T_3) produced the maximum (16.22 cm) root length although it was statically identical with T_8. The minimum root length was observed in control plot which was statistically similar with T_4, T_6 and T_9. Similar result was reported by Deshi *et al.* (1964) who noted significant effect of NPK on root length of carrot.

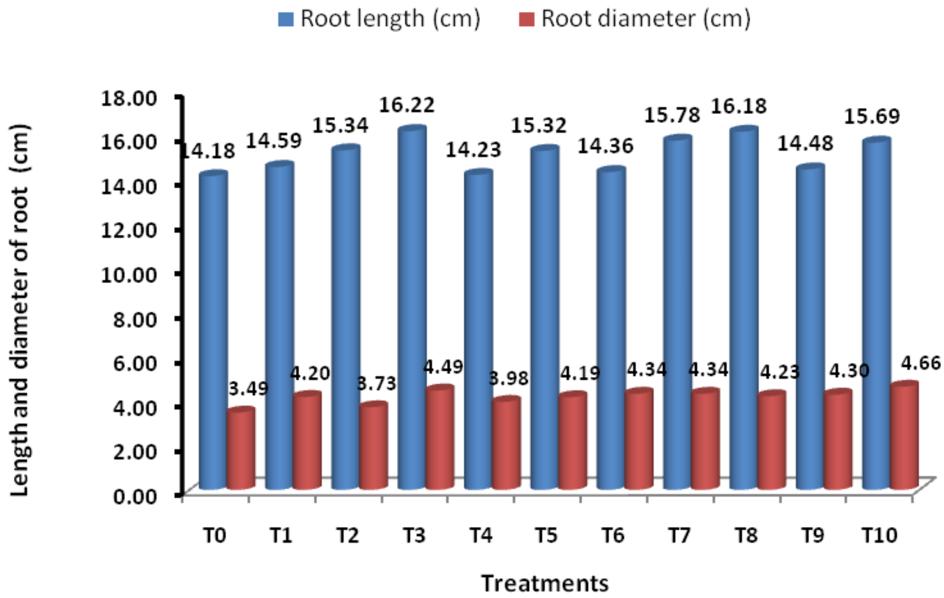

Figure 3.4.2: Length and diameter of carrot root under different nutrient management

3.4.1.4 Root diameter

The different fertilizer management had significant effect on the diameter of carrot root. The diameter varied from 3.49 to 4.66 cm (Fig. 3.4.2 and Appendix 19). The maximum (4.66 cm) root diameter was recorded in the treatment T_{10} (NPKSZnBMo) although it was statistically identical with T_3. The minimum root diameter was found in control plot which was statistically identical with NP (T_2). Deshi *et al.* (1964) found that the application of NPK fertilizers significantly increased root diameter. In general, the treatments which produced taller plant and higher number of leaves had higher root diameter. It might be due to increased photosynthesis which resulted in higher food production and storage of produced food in the roots.

3.4.1.5 Fresh weight of leaves

The fresh weight of leaves per plant was significant influenced by different nutrient management (Table 3.4.4). It varied from 46.67 to 95.83 g/plant. The maximum fresh weight was recorded in the treatment T_{10} (NPKSZnBMo) although it was statistically similar with the treatments T_1, T_4, T_5 and T_7. The minimum weight was observed in control treatment. It was observed that Phosphorus and Potassium had no effect on the fresh weight of leaves but N had significant effect.

Table 3.4.4: Effect of fertilizers on the yield and yield components of carrot.

Treatments	Fresh weight of leaf (g/plant)	F. weight of root (g/plant)	Dry matter of leaf (%)	Dry matter of root (%)	Yield (ton/ha)
T_0=Control	46.67f	106.67g	15.99b	10.97f	16.43f
T_1=N	85.17abcd	123.33f	17.23a	11.57d	19.70de
T_2=NP	75.83cde	125.83ef	15.35cd	9.537g	20.74cd
T_3=NPK	68.75e	136.67de	15.98b	13.97b	21.79bc
T_4=NPKS	89.17ab	131.83def	14.75ef	11.14ef	21.82b
T_5=NPKZn	83.92abcd	137.50d	14.55f	10.99f	24.78b
T_6=NPKB	67.50e	150.83c	16.23b	11.56d	24.14bc
T_7=NPKMo	87.92abc	131.67def	14.66ef	10.87f	21.62c
T_8=NPKSZn	75.83cde	140.42d	15.01de	11.03f	22.83bc
T_9=NPKSZnB	80.00bcde	162.08b	14.73ef	11.41de	26.40ab
T_{10}=NPKSZnBMo	95.83a	176.67a	14.87ef	15.08a	27.48a
LSD ($P \geq 0.05$)	11.53	9.838	0.359	0.288	3.279
CV (%)	8.79	4.22	1.38	1.46	4.67

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Similar result has been reported by Skrbic (1987b) who observed that nitrogen had significant effect on the dynamics of the increase in the weight of leaves in carrot. The results partially agree with Patil and Gill (1981) who noted that Nitrogen and Phosphorus application significantly increased the fresh yield of tops and agree with Farazi (1983) who reported that potassium had no effect on shoot fresh weight of carrot.

3.4.1.6 Fresh weight of root

There was significant effect of nutrient elements used on fresh weight of individual root. The fresh weight of root was varied from 106.67 to 176.67g (Table 3.4.4). The maximum weight was obtained from T_{10} (NPKSZnBMo) while the minimum was observed in control plots. Fresh weight of roots of T_3, T_4, T_5, T_7, and T_8 were statistically identical. The application of Sulphur or Molybdenum with NPK did not increase fresh weight of carrot root. In general, the higher the root weight contributed the higher yield. The increase in plant height, number of leaves, and fresh weight of leaves might have enhanced the higher vegetative growth which supplied the roots with increased food material and produced higher fresh weight of root. The result shows that P alone as well as with other nutrients increased the fresh weight of root. When B is added to NPK the fresh weight or root significantly increased (from 136.67 to 150.83 g/plant). Again when it is added with NPKSZn the fresh root weight is significantly increased. So comment may be drawn that B has significant effect on carrot root weight. These results partially agree with Sarker (1989) who reported that Potassium significantly increased the fresh weight of carrot root, Karl *et al*. (1950) who reported that higher quantity of P was needed for carrot and Kanwar and Malik (1970) who reported that B increased the root yield when applied with NPK.

3.4.1.7 Dry matter of leaves

The dry matter of leaves was significantly affected by the nutrient management. The highest dry matter (17.23%) was found when Nitrogen was applied alone to the soil (Table 3.4.4). The lowest dry matter (14.55%) was found in T_5 (NPKZn) although it was statistically identical with the treatments T_4, T_7, T_9 and T_{10}. The result revealed that nitrogen played a positive role on dry matter of leaves. But N with P or with P and K has no positive effect on dry matter of carrot leaves. The results partially agree with the findings of Ali (1994) who reported that the combination of nitrogen and potassium had no significant influence on shoot dry weight in carrot.

3.4.1.8 Dry matter of root

Different fertilizers showed significant effect on dry matter accumulation in roots of carrot (Table 3.4.4). The dry matter varied from 9.54 to 15.08%. The highest dry matter was obtained from the treatment consisting of all elements (NPK+SZnBMo) T_{10} which was significantly different from other treatments. The second highest dry matter was produced by the treatment T_3 (NPK). The lowest dry matter was obtained from T_2 (9.52%). Rest of the treatments including control had an identical effect on dry matter accumulation in root. The result partially agrees with Patil and Gill (1981) who reported that nitrogen, phosphorus and potassium significantly increased dry matter in root of carrot.

3.4.1.9 Yield of carrot root

Application of fertilizers showed differential response to carrot yield (Table 3.4.4). The yield varied widely among the treatments used and it was ranged from 16.43 to 27.48 t/ha. The highest yield (27.48 t/ha) was found in T_{10} which statistically similar to T_9. The lowest yield (16.43 t/ha) was found in control plot. The study revealed that the effect of Sulphur was negligible; Molybdenum was negative while Nitrogen, Phosphorus and Potassium have positive effect on carrot production. Zinc and Boron also showed significant positive effect on carrot production. The results partially agree with Nelyubova et al. (1972), Alekseeva and Rasskazov (1976) and Kanwar and Malik (1970). They all reported the positive impact of B on the carrot yield.

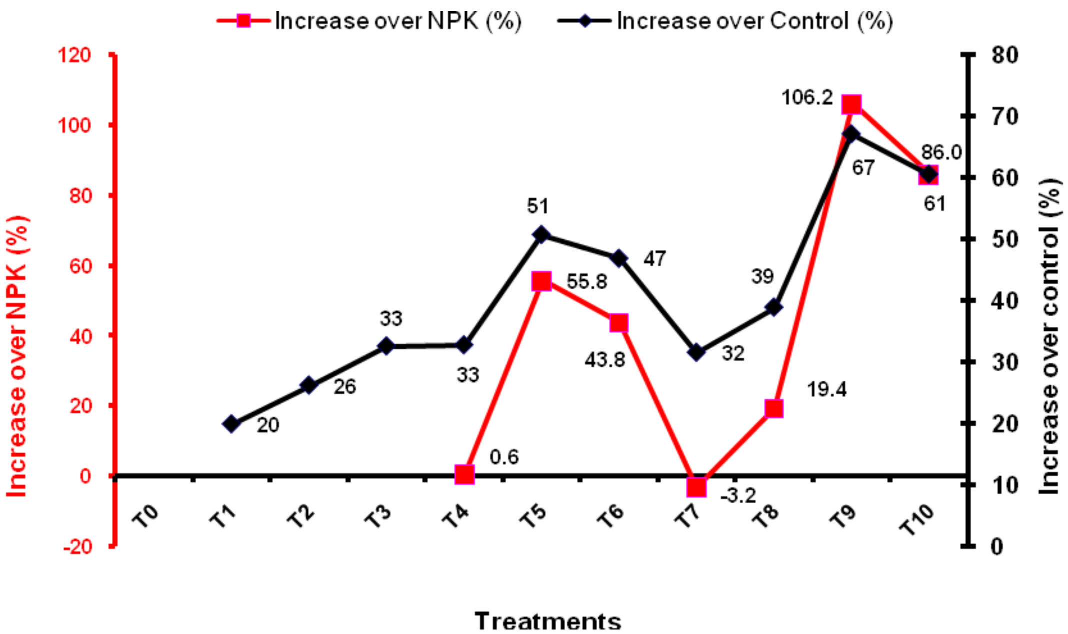

Figure 3.4.3: Increase of carrot yield over control and NPK fertilizers.

The increased production of different treatments over control and NPK are shown in Fig. 3.4.3. It shows that carrot production was increased 20% over control in T_1 (N). Similarly, 26% increase in T_2 (NP), 33% in T_3 (NPK), 33% in T_4 (NPKS), 51% in T_5 (NPKZn), 47% in T_6 (NPKB), 32% in T_7 (NPKMo), 39% in T_8 (NPKSZn), 67% in T_9 (NPKSZnB) and 61% in T_{10} (NPKSZnBMo) treatment.

When Zn and B was added individually with NPK then production was increased 14% and 11% respectively but while combined application of B and Zn increased 26% yield. The results are in accordance with Almazov and Kholuyak (1990). Sarker (1989) obtained the highest yield of 31.99 ton per hectare of carrot from the plants fertilized with the highest dose of Nitrogen (120 kg /ha). Deshi *et al*. (1964) reported that Nitrogen and

K_2O at 56 kg/ha gave the highest yield and returns. Dzebrailov (1962) observed that Nitrogen and Phosphorus increased yields by 57%.

The present results disagree with Krarup *et al.* (1984) who did not find any differences in yield of carrot using medium and high levels of NPK.

3.4.1.10 Branched root

The application of various nutrients showed significant effect on the branching in root (Table 3.4.5). The maximum branching (17.8%) was obtained in plots which received Nitrogen fertilizer (T_1). The minimum branching was noted in the treatment T_8 (9.91%).

The application of Nitrogen showed positive effect on branching of carrot root which partially agrees with Ali, (1994). He reported that roots were highly branched when the crop was fertilized with 200 kg nitrogen per hectare and the branching was increased progressively with the increasing levels of potassium fertilizer.

Table 3.4.5: Branched, cracked and marketable carrot roots as influence by different nutrient management.

Treatments	Branched root (%)	Cracked root (%)	Marketable root (%)	Non-marketable root (%)
T_0=Control	14.50	0.00	85.50	14.50
T_1=N	17.80	1.44	80.76	19.24
T_2=NP	16.75	2.17	81.08	18.92
T_3=NPK	11.15	1.90	86.95	13.05
T_4=NPKS	10.06	0.72	89.22	10.78
T_5=NPKZn	10.82	1.07	88.11	11.89
T_6=NPKB	10.35	2.13	87.52	12.48
T_7=NPKMo	10.07	3.16	86.77	13.23
T_8=NPKSZn	9.91	1.18	88.91	11.09
T_9=NPKSZnB	10.89	3.06	86.05	13.95
T_{10}=NPKSZnBMo	10.13	2.08	87.79	12.21

3.4.1.12 Marketable root

The production of marketable carrots was varied from 80.76 to 89.22 % due to different fertilizers (Table 3.4.5). The highest marketable root was found in T_4 (NPKS). The lowest marketable root was found in T_1 (N). Begum (1995) found 72.5-83.33% marketable root of carrot. Her result is closely related to the present findings.

3.4.1.11 Cracked root

Cracking of carrot roots was also influenced by fertilizers management (Table 3.4.5). The cracked root varied from 0.00 to 3.16%. The highest cracked root was obtained in T_7 while control roots were free from cracking. Buckman and Brady (1983) reported that potassium encouraging strong root system whereas Polack (1982) reported that application of K at 196 kg per hectare gave best quality of carrots. Abundant nitrogen may stimulate excessive top growth at the expense of root development, and mature roots may split (Peirce, 1981).

Experiment 2

Effect of micronutrient management on growth, yield and yield components of carrot in calcareous soils of Bangladesh

3.4.2.1 Plant height

The fertilizers containing micronutrients applied individually or in combinations showed significant effects on height of carrot plant at different growth period under investigation (Fig. 3.4.4 and Appendix 20). The height of the plant increased gradually with the passage of time and reached to its maximum level at the time of harvest. The present findings supported by Skrbic (1987b). He noted slow growth of carrot at the beginning and quite intensive growth after the formation of 7-8 leaves until maturity. The rate was increased up to 75 days and then it was decreased. The maximum plant height was recorded in all over the study period in treatment T_5 (which received Zn 2 kg, B 2 kg, Cu 1 kg, Mo 0.5 kg and Mn 4 kg/ha).

At the early stage of 30 days, plant height was ranged from 17.78 to 22.54 cm. The maximum plant height was monitored in T_5 while the shortest in T_0. The treatments T_1 and T_3; T_6 and T_2 were statistically similar.

The plant height was ranged from 24.38 - 28.90 cm after 45 days. The maximum plant height was recorded in T_5 followed by T_6, T_4, T_2, T_3 and T_1. However, the treatments T_0, T_1, T_2, T_3 and T_4 were statistically identical. When Cu was added to Zn, B, Mo and Mn, the height was increased considerably. It seems that Cu has positive effect on growth while increasing the dose of Cu as well as other micronutrients affects the growth negatively.

After 60 days, the maximum plant height was noted in T_5 followed by T_6, T_4, T_2, T_3, T_1 and T_0. The result at this growth period was more or less similar to that of 45 DAS. However, plant height was statistically similar in treatments T_0, T_1, T_2, T_3 and T_4.

The trend of plant height after 75 days was more or less similar to that of 60 days. The range was 44.71 - 49.23cm. The maximum plant height was observed in T_5 followed by T_6, T_4, T_2 and T_3. After 90 days, it was 50.47-58.55cm. The maximum plant height was recorded in T_5 as before. The response of Cu on plant growth was similar as recorded in the previous growth periods. However, the treatments T_1, T_2, T_4 and T_6 were statistically similar.

At harvest, the height ranged from 52.03 - 60.30 cm. The maximum plant height was found in T_5 as before which followed by T_3, T_1, T_6, T_4, and T_2. The response of Cu at this growth period was similar as before. However, the treatments T_1, T_2, T_4 and T_6 were statistically similar.

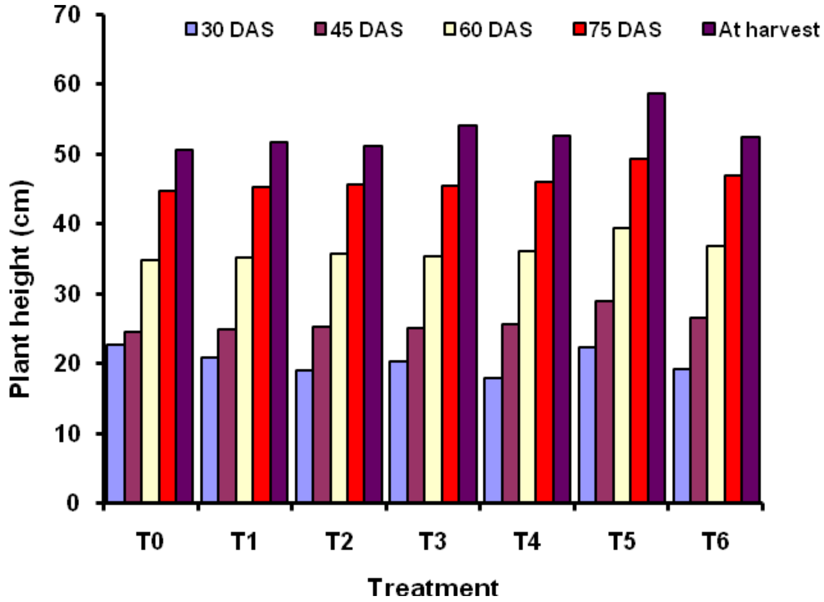

Figure 3.4.4: Height of carrot plant at five growth periods as affected by different minutrient management

The results revealed that all the micronutrients are essential for better growth of carrot plant while over doses is harmful for growth. Similar observation has been reported by Maurya and Singh (1985) in radish.

3.4.2.2 Number of Leaves

Number of leaves is an important factor playing vital role in photosynthesis having impact on final yield of vegetable crops. In the present study, highest number of leaves was observed in T_5 throughout the whole study period indicating Cu sensitivity to carrot (Fig. 3.4.5 and Appendix 21).

At the initial growth stage of 30 days the number of leaves varied from 6.91 to 7.68 and was insignificant although the highest number was recorded in the treatment T_5. After 45 days, the range of number of leaves was from 7.07 to 8.47. The maximum leaves was recorded in T_5 followed by T_2, T_0, T_3, T_4, T_6 and the minimum in T_1. At this growth period all the treatments including the control except T_5 were statistically insignificant.

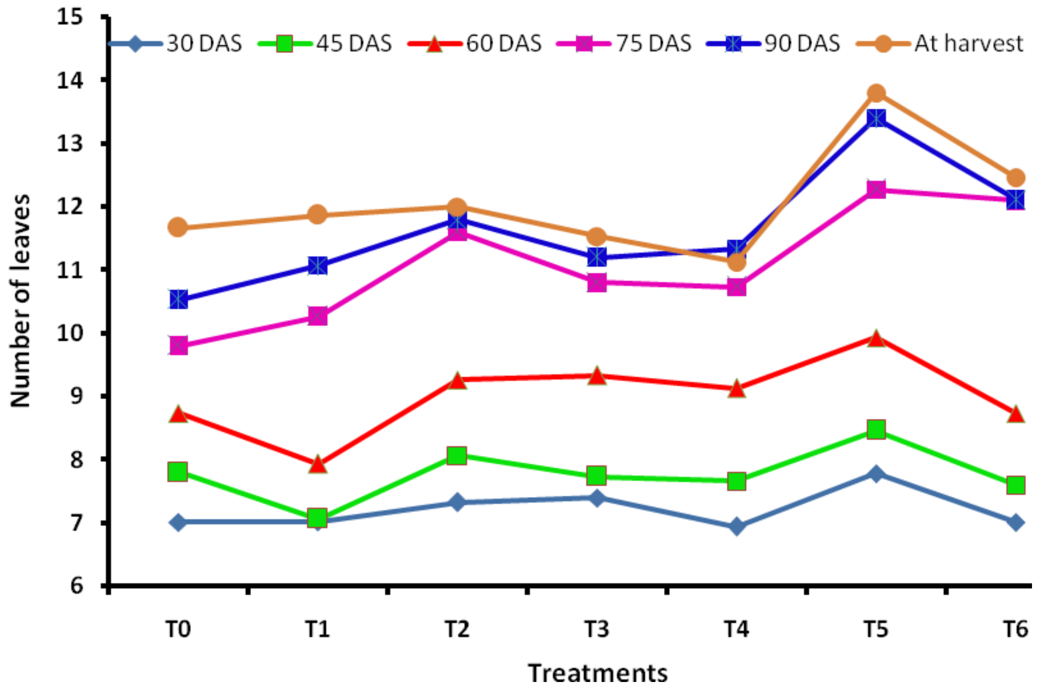

Figure 3.4.5: Number of leaves of carrot plant at different days as affected by different micronutrient management.

The maximum number (9.93) of leaves after 60 days was recorded in T_5 followed by T_3, T_2, T_4, T_6 and T_0 while the minimum in T_1. The treatments T_0, T_2, T_3, T_4, and T_6 were statistically similar at this growth period. After 75 days, the number of leaves ranged from 9.80 to 12.27. The maximum was recorded in T_5 as before which was followed by T_6, T_2 while the minimum was in the treatment T_0. The treatments T_2, T_3, T_4 were found statistically similar. The maximum number (13.40) of leaves after 90 days was recorded in T_5 followed by T_6, T_2, T_4, T_3 and T_1 while the minimum (10.53) in the control plots. At harvest the leaf number ranged from 11.13 to 13.80. The maximum number was recorded in T_5 while the minimum in treatment T_4.

The results showed that Zn, B, Mo or Mn have no significant effect on carrot leaf production as these fertilizers when added to NPK did not able to increase leaf number. The response of Cu was prominent. When Cu was added to NPK along with other micronutrients resulted in highest leaf number while higher dose of Cu as well as other micronutrients showed negative effect on leaf number. However, the result indicates that treatment T_5 having Zn 2 kg, B 2kg, Cu 1kg, Mo 0.5kg and Mn 4 kg/ha is the best for the highest number of leaf having direct impact on the photosynthesis and carrot production under the studied environment.

3.4.2.3 Root diameter and length

The diameter of carrot root was not significantly affected by the micronutrients used in this investigation (Fig. 3.4.6 and Appendix 22). It was ranged from 3.93 to 4.62 cm. The maximum diameter was recorded in unfertilized control plots although it was statistically identical with $T_{5.}$ The minimum diameter was found in the treatment T_6. There was no significant difference in root diameter in the treatments T_1, T_2 $T_{3,}$ T_4 and T_6. It was observed that higher doses of micronutrients showed negative effect on root diameter.

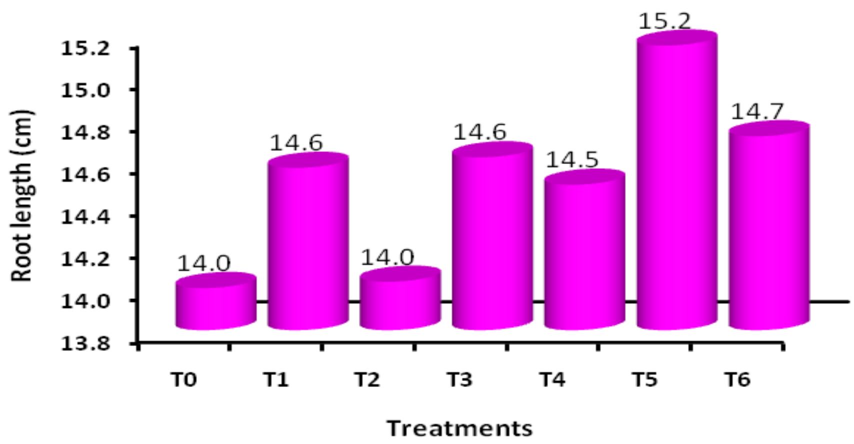

Figure 3.4.6: Root length of carrot as affected by different micronutrient managements.

The length of carrot root ranged from 14.00 to 15.15 cm. The longest root was found in T_5 while the shortest was recorded in T_1. The treatments T_1, T_2, T_3, T_4 and T_6 are statistically similar each other but have significant difference with T_0. The results indicated that the micronutrients Zn, B, Mo and Mn have no significant effect on the length of carrot root while Cu has significant and positive effect although the higher doses of Cu along with other micronutrients decreased it.

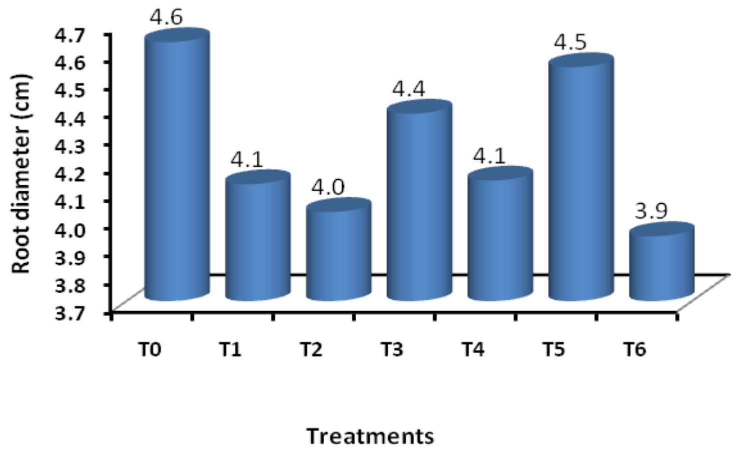

Figure 3.4.7: Root diameter of carrot as affected by different micronutrient managements.

3.4.2.4 Fresh weight of root

A significant difference was noted in fresh weight of carrot root due to micro-nutrient management (Table 3.4.4). It ranged from 107.3 to 147.3 g/plant. The heaviest root was recorded in the treatment T_5 while the lightest was observed in T_0. The treatments T_1, T_2, T_3, T_4 and T_6 were statistically similar among themselves. The results showed that the effect of Zn and B on root weight was not prominent while lower dose of Cu and other nutrient have prominent effect.

3.4.2.5 Weight of shoot

The shoot weight varied from 51.67 to 84.67 g/plant (Table 3.4.4). The maximum weight was observed in T_5 while the minimum in T_1. The treatments T_0, T_4, and T_6 were statistically identical. The results revealed that the micronutrients Zn, B, Mo and Mn had no effect on shoot weight of carrot while the effect of Cu was significant and prominent only at the lower dose. When the dose of Cu was increased and applied with higher doses of micro-nutrients it decreased shoot weight. The increase in the various attributes such as plant height, number of leaves per plant might have enhanced the higher vegetative growth which supplied the roots with increased food material and produced higher fresh weight of individual root.

Table 3.4.6: Yield and yield contributing characters of carrot as affected by different micro-nutrient management.

Treatments	Wt. of Root/ (g/plant)	Wt. of shoot (g/plant)	Root Yield (t/ha)	Yield increase over NPK (%)
T_0 =(control)	107.3c	66.00b	21.68d	-
T_1=Zn_2B_2	119.5bc	51.67d	24.13c	11.30
T_2= $Zn_2B_2Mo_{0.5}$	122.0bc	57.27c	24.65c	13.69
T_3= $Zn_3B_3Mo_1$	120.0bc	52.67 cd	24.24c	11.80
T_4= $Zn_2B_2Mo_{.5}Mn_4$	138.7ab	67.33b	28.01b	29.19
T_5= $Zn_2B_2Cu_1Mo_{0.5}Mn_4$	147.3a	84.67a	29.76a	37.26
T_6= $Zn_3B_3Cu_2Mo_1Mn_8$	123.0bc	64.33b	24.85bc	14.62
LSD (0.05)	22.820	4.841	1.369	
CV (%)	10.23	4.29	10.23	

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

3.4.2.6 Root Yield

It was observed that yield of carrot was significantly affected by the micro-nutrient management. The highest yield (29.76 ton) as well as 37.26% increase over control was obtained from the treatment T_5 while the lowest was recorded in T_0 (Table 3.4.4). The result revealed that micro-nutrients have significant and positive effect on carrot yield. The results indicated that the application of Zn and B increased the yield while the addition of Mo with higher dose of Zn and B did not increase the yield. It was observed that when lower dose (0.5 kg/ha) Mo applied with lower dose of Zn and B increased the yield 13.69% but when the dose of Mo was doubled and applied with higher dose of Zn and B it did not increase the yield. When Mn was applied to the soil along with Zn, B and Mo it increased the yield by 29.19%. Similarly, when Cu was added with lower dose of Zn, B, Mo and Mn it increased the yield by 37.26% which the highest yield. The results revealed that lower doses of micronutrients are necessary to increase the yield of carrot but higher doses are not economic for its production.

The results obtained in the present investigation agree with Szmidt (1980) who observed that soil boron content above 2.0 mg or below 0.5 mg boron per litre resulted decrease in root yield of carrot. Kononovich (1971) obtained increased germination and yield of carrot using boric acid or CuSO4 while Kelly *et al*. (1952) obtained the highest yield at 2.00 ppm boron solution. Similarly, Kanwar and Malik (1970) reported increased yield when B was applied in combination with lower dose of NPK.

Summary and Conclusion

Experiment 1:

The plant height and number of leaves of carrot plant were significantly influenced by different nutrient management. The maximum plant height (51.08 cm) was produced by the treatment containing NPK. The leaf production was significantly increased by various nutrients. The maximum leaves (15.38) were produced by the plot receiving NPKZn.

Root length was significantly affected by the fertilizers with a range of 14.17 to 16.22 cm. Application of NPK produced the maximum (16.22 cm) root length. The maximum diameter (4.66 cm) of carrot root was recorded in the treatment having all the nutrients which indicated that all the nutrients contributed carrot diameter.

The maximum fresh weight of leaves (95.83 g/plant) was recorded in the treatment T_{10} (NPKSZnBMo) although it was statistically similar with the treatments T_1, T_4, T_5 and T_7. When N was added with control the leaf production became almost double (from 46.67 to 85.17 g/plant). But when P was added with NP it became 75.83 and in NPK became 68.75. So it can be stated that Phosphorus and Potassium had no effect on the fresh weight of leaves but N had significant effect.

The maximum fresh weight of root was obtained in the treatment T_{10} (NPKSZnBMo) while the minimum was noted in control treatment. The application of Sulphur or Molybdenum with NPK did not increase fresh weight of carrot root (from 136.67 to 131.83 and 131.67 g/plant respectively), while B increased it (150.83 g/plant in NPKB). Dry matter content of leaves as well as roots was significantly affected by the nutrients used. The highest dry matter of leaves (17.23%) was noted in the treatment T_1 (having only nitrogen) while the highest dry matter of root (15.08%) was found in the plot receiving all nutrients and the lowest (9.53%) in plot receiving NP only.

All the treatments used in this investigation increased the yield carrot root. The highest yield (27.48 t/ha) which was 67.48% higher over control was obtained from the plot receiving all the nutrients. The highest yield in this treatment might be due to higher individual root weight, higher number of leaves per plant, higher dry matter content of root and positive enhancement of other parameters like plant height, root diameter, fresh weight of leaves per plant recorded by this treatment. The study revealed that the effect of Sulphur was negligible (21.79t/ha in NPK and 21.82 t/ha in NPKS); Molybdenum was negative (21.62 t/ha in NPKMo) while Nitrogen, Phosphorus and Potassium have positive effect on carrot production. Zinc and Boron also showed significant effect on carrot production. The effects of different fertilizers on carrot yield was recorded in the order of NPKSZnBMo>NPKSZnB>NPKZn>NPKB>NPKSZn>NPKS>NPK>NPKMo> NP>NK>N.

Branching of carrot root is an undesirable character which was the highest (17.8%) in plot receiving Nitrogen only while S (10.06%) and Zn (10.82%) reduced it when added with NPK (11.15%). The highest cracked root (3.16%) was obtained in plot receiving NPK with Mo while roots in control were free from cracking. The results showed that S reduced cracking when added with NPK (1.9% in NPK and 0.72 in NPKS). The highest marketable root (89.22%) was produced by the plot which received NPK+S. This might be due to reduction of cracking of carrot root by Sulphur.

Experiment 2

The micronutrients exhibited significant effects on height of carrot plant at different growth period under investigation. At the time of harvest, the maximum plant height (60.30 cm) was obtained from the plot which received Zn 2 kg, B 2 kg, Cu 1 kg, Mo 0.5 kg and Mn 4 kg/ha (T_5). Higher doses of these nutrients reduced plant growth which indicated that all the micronutrients are essential for better growth of carrot plant while over doses is harmful for growth.

Number of leaves is an important factor playing vital role in photosynthesis having impact on the yield of vegetable crops. The highest number of leaves (13.80) at harvest was observed in $T_{5.}$ The results showed that Zn, B, Mo or Mn have no significant effect on carrot leaf production as these fertilizers when added to NPK did not able to increase leaf number (11.13 whereas 11.67 in control). The response of Cu was prominent. When Cu was added to NPK along with other micronutrients resulted in highest leaf number while higher dose of Cu as well as other micronutrients showed negative effect on leaf number.

The maximum diameter (4.6 cm) of carrot root was recorded in the control plot which received only NPK while the minimum (3.9 cm) was obtained from the receiving all micronutrients. The results revealed that micro nutrients are less effective on root diameter compared to macro nutrients. The maximum root length (15.2 cm) was found in T_5 while the minimum in T_1 (14.0 cm). The results indicated that the micronutrients Zn, B, Mo and Mn have no significant effect on the length of carrot root while Cu has positive effect (15.2 cm in ZnBCuMoMn at lower dose from 14.5 cm in ZnBMoMn) although the higher doses of Cu along with other micronutrients decreased it.

The results showed that micro nutrients have significant effect on fresh weight of carrot root. The maximum root weight (147.3 g/plant) was recorded in the treatment T_5 while the minimum (107.3 g/plant) was observed in control. The effect of Zn and B on root weight was prominent (from control to 119.5 g/plant in Zn_2B_2) while addition of Mo increased the fresh weight but insignificant. The maximum weight of shoot (84.67 g/plant) was observed in T_5 while the minimum (51.67 g/plant) in T_1. The results revealed that the micronutrients Zn, B, M and Mn had no effect on shoot weight of carrot while the effect of Cu was significant and prominent only at the lower dose ($Zn_2B_2Cu_1Mo_{0.5}Mn_4$).

The yield of carrot was significantly affected by the micro nutrient management. The highest yield (29.76 ton) as well as 37.26% increase over control was obtained from the treatment T_5 while the lowest (21.68 ton) was recorded in control. It was observed that when lower dose (0.5 kg/ha) of Mo applied with lower dose of Zn and B increased the yield 13.69% but when the dose of Mo was doubled and applied with higher dose of Zn and B it did not increase the yield. When Mn was applied to the soil along with Zn, B and Mo it increased the yield by 29.19%. Similarly, when Cu was added with Zn, B, Mo and Mn at lower dose it increased the yield by 37.26% which the highest yield. The results revealed that lower doses of micronutrients ($Zn_2B_2Cu_1Mo_{0.5}Mn_4$) are necessary to increase the yield of carrot but higher doses are not economic for its production.

From the above two experiments it is observed that in the first experiment with the nutrients NPKSZnBMo carrot production reached 27.48 t/ha and in the second experiment with $Zn_2B_2Cu_1Mo_{0.5}Mn_4$ (with basal dose N-150, P-50 and K-100) it reached 29.76 t/ha. This revealed that 150kgN 50kg P 100kg K 2kg Zn 2kg B 1kg Cu 0.5kg Mo and 4kg Mn is essential to produce maximum carrot yield in the experimented soil.

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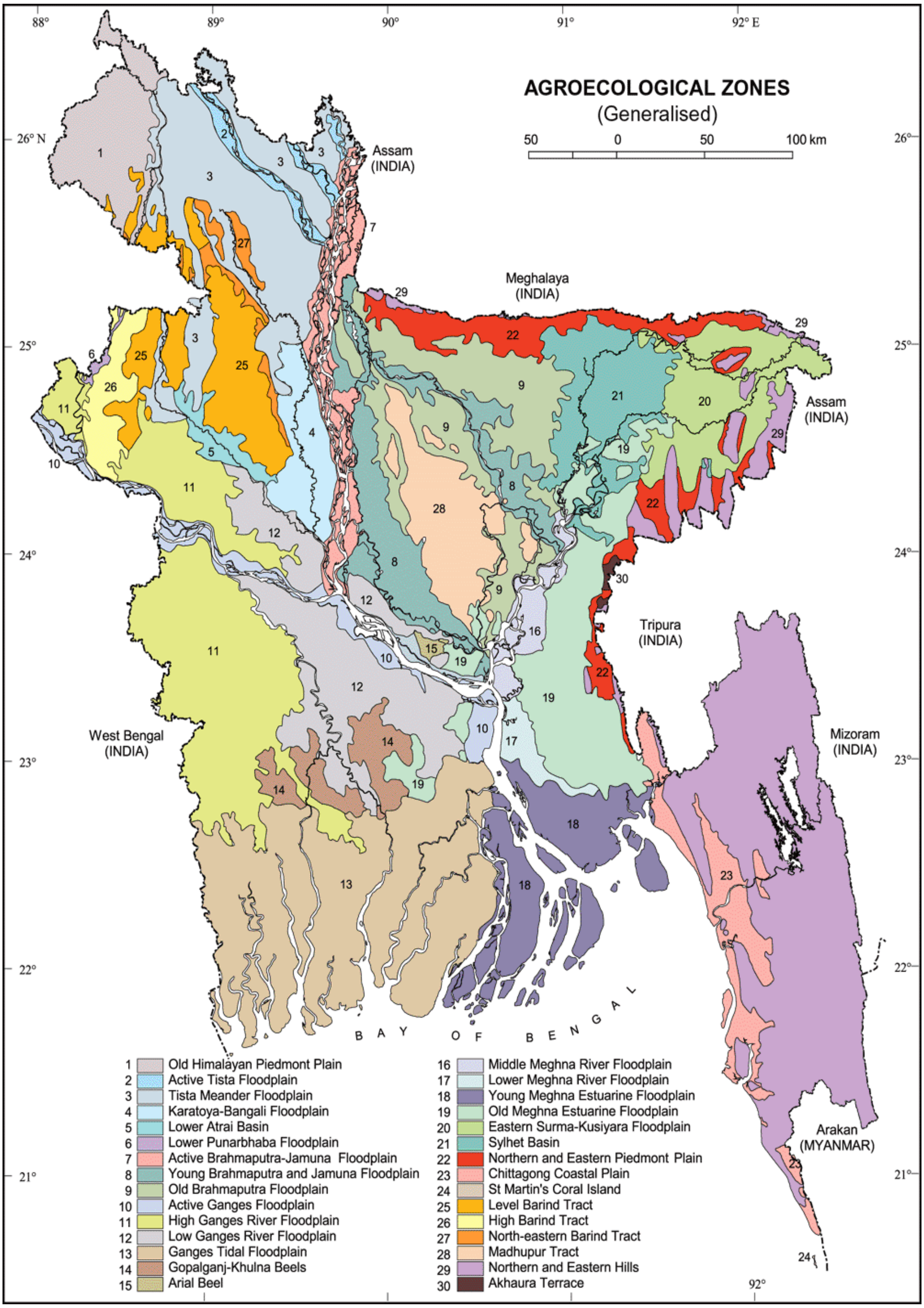
Appendix

Appendixes

Appendix 1: Agro Ecological Zones of Bangladesh (Source: SRDI, Dhaka)



Appendix 2: Initial Physico-chemical properties of experimental soil.

Soil Properties	2008	2009	Critical level
Texture	Silty clay loam	Silty clay loam	-
pH	7.2	7.2	-
OM	0.62%	0.61%	-
Total N	0.04(%)	0.04(%)	0.12(%)
Available P	29.0 µg/g	29.3 µg/g	14.0 µg/g
Exchangeable K	0.41 meq/100g	0.39 meq/100g	0.20 meq/100g
Available S	11.8 µg/g	11.4 µg/g	14.0 µg/g
Available B	0.48 µg/g	0.42 µg/g	0.2 µg/g
Available Zn	1.32 µg/g	1.29 µg/g	0.6 µg/g
Available Cu	3.45 µg/g	3.45 µg/g	0.2 µg/g
Exchangeable Mg	1.67 meq/100g	1.70 meq/100g	0.80 meq/100g
Available Mn	48.7 µg/g	48.1 µg/g	1.0 µg/g
Available Fe	78.0 µg/g	77.3 µg/g	4.0 µg/g
Exchangeable Ca	4.05 meq/100g	4.00 meq/100g	2.0 meq/100g

Appendix 3a: The metrological data in respect of temperature, rainfall, relative humidity of the experimental site during November 2008-March 2009.

Month	Air temp.(^{0}C)			Rainfall (mm)	Soil temp·(^{0}C)			Relative humidity (%)
	Max.	Min.	Mean		05 cm	10 cm	15 cm	
Nov’08	29.43	17.43	23.43	0.0	24.2	25.5	26.1	86.4
Dec’08	25.68	10.48	18.08	19.2	19.2	20.5	21.1	80.90
Jan’09	18.52	9.45	13.99	0.0	16.4	17.2	18.2	84.23
Feb’09	28.36	13.11	20.74	0.0	19.4	20.4	20.8	79.68
Mar’09	33.51	18.61	26.06	0.0	23.5	24.2	24.5	73.9

Appendix 3b: The metrological data in respect of temperature, rainfall, relative humidity of the experimental site during November 2008-March 2009.

Month	Air temp.(^{0}C)			Rainfall (mm)	Soil temp·(^{0}C)			Relative humidity (%)
	Max.	Min.	Mean		05 cm	10 cm	15 cm	
Nov’08	29.30	17.80	23.50	0.0	24.1	25.3	26.2	85.7
Dec’08	25.38	10.90	18.31	0.0	19.3	20.6	21.1	80.40
Jan’09	21.39	09.38	14.87	0.0	16.1	17.1	18.2	84.31
Feb’09	27.79	13.19	20.96	2.5	19.2	20.6	21.1	77.60
Mar’09	32.44	19.41	25.87	0.0	23.1	24.3	24.9	73.3

Appendix 4: The spread of cabbage plant as influenced by different nutrient combinations.

Treatments	Foliage coverage (cm) at				
	30 DAT	45 DAT	60 DAT	75 DAT	Harvest
T_0=Control	28.73h	33.57i	39.57h	43.34h	42.22h
T_1=N	31.47g	37.77h	45.60g	53.27g	52.02g
T_2=NP	34.10f	43.30g	52.45f	59.29f	56.34f
T_3=NPK	39.60cd	48.53de	58.30cd	63.66de	61.93de
T_4=NPKS	36.44e	45.00f	55.93e	62.73e	61.40e
T_5=NPKZn	38.47d	47.63e	57.40de	64.26d	62.80d
T_6=NPKB	45.64a	54.43a	65.33a	71.45a	70.76a
T_7=NPKMo	41.10e	50.70bc	59.29bc	67.33c	65.30c
T_8=NPKSZn	38.53d	48.53de	58.20cd	64.41d	62.75e
T_9=NPKSZnB	39.37cd	49.43ed	58.37cd	68.37c	67.50b
T_{10}=NPKSZnBMo	42.83b	51.24b	60.37b	69.86b	66.50b
LSD ($P \geq 0.05$)	1.68	1.51	1.62	1.27	1.35
CV (%)	2.61	1.9	1.72	1.19	1.52

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 5: Height of the cabbage plant as influenced by different nutrient combinations.

Treatments	Plant height (cm) at				
	30 DAT	45 DAT	60 DAT	75 DAT	Harvest
T_0=Control	23.53h	24.70f	25.79f	26.44g	26.31g
T_1=N	26.30g	29.77e	31.07e	32.00f	31.45f
T_2=NP	28.10ef	30.32de	32.27d	34.02e	33.76d
T_3=NPK	30.27bcd	34.78a	35.74b	36.83b	36.52b
T_4=NPKS	26.73fg	30.81cde	32.31d	33.40e	32.96de
T_5=NPKZn	29.09de	31.22bcd	33.11cd	34.15e	33.70d
T_6=NPKB	32.42a	35.13a	36.93a	38.23a	37.89a
T_7=NPKMo	31.37ab	32.25b	33.80c	35.33cd	35.01c
T_8=NPKSZn	28.96de	30.70cde	32.77d	33.82e	33.33de
T_9=NPKSZnB	29.65cd	31.87bc	32.49d	34.49de	33.88cd
T_{10}=NPKSZnBMo	30.67bc	32.19b	33.76c	35.80c	35.42bc
LSD ($P \geq 0.05$)	1.42	1.17	0.94	1.00	1.22
CV (%)	2.9	2.19	1.69	1.73	1.60

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 6: Length of largest leaf of cabbage at different growth period as influenced by different nutrient combinations.

Treatments	Largest leaf length (cm) at				
	30 DAT	45 DAT	60 DAT	75 DAT	Harvest
T_0=Control	17.83f	22.71d	24.09f	24.97h	24.45g
T_1=N	20.15e	28.11c	29.13e	30.43g	29.96f
T_2=NP	22.413d	28.96c	31.59d	32.10f	31.98e
T_3=NPK	24.83bc	31.11b	33.83bc	34.73cd	34.56bc
T_4=NPKS	24.43c	30.75b	33.67bc	33.93e	33.43d
T_5=NPKZn	24.95bc	30.93b	34.73b	35.37bc	35.07b
T_6=NPKB	26.19a	32.36a	35.97a	38.33a	37.83a
T_7=NPKMo	24.27c	30.96b	33.73bc	34.10de	33.72cd
T_8=NPKSZn	24.00c	30.57b	33.20c	34.07de	33.87c
T_9=NPKSZnB	24.20c	31.12b	34.17bc	35.17bc	34.67bc
T_{10}=NPKSZnBMo	25.87ab	31.65ab	34.70b	35.63b	34.93bc
LSD ($P \geq 0.05$)	1.11	1.09	0.95	0.67	0.80
CV (%)	2.77	2.12	1.71	1.16	1.21

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 7: Length of largest leaf of cabbage at five growth period as affected by micro-nutrient management.

Treatments	Largest leaf length (cm) at				
	30 DAT	45 DAT	60 DAT	75 DAT	Harvest
T_0=Control	26.73e	28.27g	30.53e	31.97d	32.25c
T_1=Zn_2B_2	27.67cde	32.5d	33.97c	34.79c	35.53b
T_2= $Zn_2B_2Mo_{0.5}$	30.70a	35.90a	36.90a	37.50a	38.02a
T_3=$Zn_3B_3Mo_1$	28.62bcd	30.07f	31.40d	31.63d	32.37c
T_4=$Zn_2B_2Mo_{.5}Mn_4$	29.68ab	33.82c	35.23b	35.33bc	35.99b
T_5= $Zn_2B_2Cu_1Mo_{0.5}Mn_4$	29.30abc	35.03b	36.26a	36.88a	37.97a
T_6= $Zn_3B_3Cu_2Mo_1Mn_8$	26.99de	31.63e	35.19b	35.90b	37.47a
LSD (0.05)	1.694	0.7484	0.8249	0.9809	0.6798
CV (%)	3.34	1.30	1.36	1.58	1.07

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 8: Foliage coverage of cabbage at five growth period as affected by micro-nutrient management.

Treatments	Foliage coverage (cm) at				
	30 DAT	45 DAT	60 DAT	75 DAT	Harvest
T_0=Control	43.95 e	47.78 d	49.77 e	53.60 e	54.50 e
T_1=Zn_2B_2	50.13 cd	53.97 bc	59.17 c	63.00 c	63.90 c
T_2= $Zn_2B_2Mo_{0.5}$	52.73 a	55.90 a	60.79 b	64.62 b	65.52 b
T_3=$Zn_3B_3Mo_1$	50.62 bcd	54.12 bc	60.43 b	64.27 b	65.17 b
T_4=$Zn_2B_2Mo_{.5}Mn_4$	51.27 abc	54.77 ab	62.96 a	66.79 a	67.69 a
T_5= $Zn_2B_2Cu_1Mo_{0.5}Mn_4$	52.07 ab	55.90 a	63.19 a	67.02 a	67.92 a
T_6= $Zn_3B_3Cu_2Mo_1Mn_8$	49.07 d	52.90 c	56.77 d	60.60 d	61.50 d
LSD (0.05)	1.631	1.322	1.089	1.089	1.089
CV (%)	1.84	1.39	1.04	0.97	0.96

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 9: Height of cabbage plant at five growth period as affected by micro-nutrient management.

Treatments	Plant height at				
	30 DAT	45 DAT	60 DAT	75 DAT	Harvest
T_0=Control	21.30c	25.27c	26.63d	8.90d	29.07d
T_1=Zn_2B_2	23.47b	26.05c	28.85c	31.11c	31.28c
T_2= $Zn_2B_2Mo_{0.5}$	25.07a	27.24b	30.04b	32.31b	32.47b
T_3=$Zn_3B_3Mo_1$	24.67a	27.73ab	30.53ab	32.79ab	32.96ab
T_4=$Zn_2B_2Mo_{.5}Mn_4$	24.00ab	28.10ab	30.90ab	33.16ab	33.33ab
T_5= $Zn_2B_2Cu_1Mo_{0.5}Mn_4$	24.71a	27.21b	30.01b	32.28b	32.44b
T_6= $Zn_3B_3Cu_2Mo_1Mn_8$	24.53ab	28.61a	31.41a	33.68a	33.85a
LSD (0.05)	1.064	0.9210	0.9481	0.9481	0.9481
CV (%)	2.50	1.91	1.79	1.66	1.66

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 10: Number of leaves in cauliflower plants at four growth periods as affected by different fertilizer combinations.

Treatments	Number of leaf at			
	30 DAT	45 DAT	60 DAT	Harvest
T_0=Control	11.60b	17.67bc	18.05c	19.55bc
T_1=N	11.67ab	16.53bcd	19.25bc	21.78abc
T_2=NP	12.07ab	18.03ab	20.34b	22.07ab
T_3=NPK	11.80ab	16.87bcd	21.15a	22.62a
T_4=NPKS	11.80ab	16.40cd	19.75bc	21.23abc
T_5=NPKZn	11.80ab	17.73bc	20.85ab	22.11ab
T_6=NPKB	12.40ab	15.80d	21.54a	21.81abc
T_7=NPKMo	12.07ab	17.70bc	22.25a	23.00a
T_8=NPKSZn	12.07ab	17.53bc	21.30a	22.67a
T_9=NPKSZnB	12.87ab	19.30a	19.65bc	20.11abc
T_{10}=NPKSZnBMo	13.20a	17.50bc	18.45c	19.11c
LSD ($P \geq 0.05$)	1.38	1.32	1.8	2.26
CV (%)	6.67	4.47	5.20	7.01

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 11: Length of the largest leaf of cauliflower at four growth periods as affected by different fertilizer managements.

Treatments	Largest leaf length (cm) at			
	30 DAT	45 DAT	60 DAT	Harvest
T_0=Control	21.49g	29.15f	30.92g	31.52e
T_1=N	23.07g	32.08de	35.22ef	36.72cd
T_2=NP	25.01f	33.01cde	36.53de	38.25c
T_3=NPK	26.56def	34.23bc	37.63cd	40.25b
T_4=NPKS	29.03bc	36.36a	39.47b	40.97b
T_5=NPKZn	27.31cde	33.87cd	35.28ef	37.36c
T_6=NPKB	26.62def	32.29de	34.42f	36.22d
T_7=NPKMo	25.85ef	31.62e	33.60f	35.75d
T_8=NPKSZn	28.34bcd	34.34bc	38.79bc	40.29b
T_9=NPKSZnB	29.62b	35.85ab	41.21a	43.71a
T_{10}=NPKSZnBMo	31.90a	36.57a	42.18a	44.63a
LSD ($P \geq 0.05$)	1.82	1.66	1.65	1.62
CV (%)	3.98	2.90	2.63	2.71

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 12: Breadth of largest leaf of cauliflower at three growth periods as affected by different fertilizer combinations.

Treatments	Largest leaf breath (cm) at			
	30 DAT	45 DAT	60 DAT	Harvest
T_0=Control	8.83f	12.16e	13.28f	13.65d
T_1=N	9.95e	13.28d	14.58ef	15.25c
T_2=NP	10.73d	14.39c	15.63de	16.34c
T_3=NPK	11.80c	15.65ab	17.80bc	19.32bc
T_4=NPKS	11.79c	15.60ab	19.13ab	20.88ab
T_5=NPKZn	13.06ab	14.73bc	18.17bc	19.92ab
T_6=NPKB	13.81a	15.14bc	19.11ab	20.86ab
T_7=NPKMo	11.11cd	13.01de	16.77cd	18.52bc
T_8=NPKSZn	12.80b	14.80bc	17.38bcd	19.13bc
T_9=NPKSZnB	13.42ab	15.42abc	19.15ab	20.91a
T_{10}=NPKSZnBMo	13.72a	16.39a	20.33a	22.08a
LSD (P≥0.05)	0.74	1.01	1.91	2.24
CV (%)	3.63	4.04	6.45	4.45

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 13: Spread of cauliflower plants at four growth periods as affected by different nutrient management.

Treatments	Plant spread (cm) at			
	30 DAT	45 DAT	60 DAT	Harvest
T_0=Control	35.63g	39.97h	41.95f	42.65f
T_1=N	39.01f	46.33g	52.91e	54.62ef
T_2=NP	40.90e	48.37f	54.47e	55.34e
T_3=NPK	41.77de	50.10ef	56.82d	57.32de
T_4=NPKS	45.40a	53.07cd	58.07cd	59.57cd
T_5=NPKZn	43.65bc	52.70cd	57.13d	58.85cd
T_6=NPKB	43.87b	53.47bc	59.08c	60.58c
T_7=NPKMo	42.57bcd	51.35de	56.78d	58.28d
T_8=NPKSZn	45.24a	55.17ab	62.69ab	64.24ab
T_9=NPKSZnB	42.40cd	53.40bc	61.73b	63.23b
T_{10}=NPKSZnBMo	45.40a	56.73a	63.73a	65.45a
LSD (P≥0.05)	1.30	1.75	1.66	2.00
CV (%)	1.81	2.02	1.72	1.95

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 14: Height of cauliflower plant at four growth periods as affected by different fertilizer combinations.

Treatments	Plant height (cm) at			
	30 DAT	45 DAT	60 DAT	Harvest
T_0=Control	20.69g	25.33d	29.76h	32.24g
T_1=N	22.00ef	28.62c	32.60fg	36.73e
T_2=NP	23.57cd	30.70ab	34.00e	39.15d
T_3=NPK	24.97a	31.48a	35.84cd	40.94c
T_4=NPKS	24.81ab	30.82ab	33.01fe	38.11d
T_5=NPKZn	23.73bcd	28.73c	31.67g	35.77ef
T_6=NPKB	22.90de	30.08b	39.00a	44.18ab
T_7=NPKMo	21.70fg	27.67c	35.70d	40.87cd
T_8=NPKSZn	22.77def	30.33b	36.91bc	41.01c
T_9=NPKSZnB	23.85abcd	31.67a	38.01ab	43.11b
T_{10}=NPKSZnBMo	24.31abc	31.50a	38.68a	44.78a
LSD ($P \geq 0.05$)	1.10	1.05	1.11	1.20
CV (%)	2.79	2.08	1.86	1.95

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 15: Length of largest leaf of cauliflower at different growth periods as affected by different micro-nutrient management.

Treatments	Length of largest leaf (cm) at			
	30 DAT	45 DAT	60 DAT	Harvest
T_0=Control	31.17b	36.22 b	42.61d	42.87d
T_1=Zn_2B_2	33.68ab	40.08ab	49.41a	49.67a
T_2= $Zn_2B_2Mo_{0.5}$	34.65ab	39.70ab	43.69d	43.96d
T_3=$Zn_3B_3Mo_1$	34.81ab	39.86ab	47.32b	47.59b
T_4=$Zn_2B_2Mo_{.5}Mn_4$	36.52a	41.57a	46.93bc	47.20bc
T_5= $Zn_2B_2Cu_1Mo_{0.5}Mn_4$	34.03ab	39.08ab	45.78c	46.04c
T_6= $Zn_3B_3Cu_2Mo_1Mn_8$	35.27ab	40.32ab	46.44bc	46.71bc
LSD (0.05)	3.832	3.804	1.318	1.318
CV (%)	6.28	5.41	1.61	1.60

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 16: Foliage coverage of cauliflower plant at different growth periods as affected by different micro-nutrient management.

Treatments	Foliage coverage (cm) at			
	30 days	45 days	60 days	Harvest
T_0=$N_{150}P_{50}K_{100}$	38.73e	39.98c	43.72c	44.02c
T_1=NPK+Zn_2B_2	49.17bc	52.79b	57.12b	57.42b
T_2= NPK +$Zn_2B_2Mo_{0.5}$	46.48d	52.17b	56.51b	56.81b
T_3= NPK +$Zn_3B_3Mo_1$	48.41c	56.67a	61.01a	61.31a
T_4= NPK +$Zn_2B_2Mo_{.5}Mn_4$	50.93a	55.57a	59.90a	60.20a
T_5= NPK +$Zn_2B_2Cu_1Mo_{0.5}Mn_4$	48.47c	51.93b	56.27b	56.57b
T_6= NPK +$Zn_3B_3Cu_2Mo_1Mn_8$	49.77b	52.13b	56.47b	56.77b
LSD (0.05)	1.156	1.411	1.470	1.470
CV (%)	1.37	1.54	1.48	1.47

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 17: Height of cauliflower plant at different growth periods as affected by different micro-nutrient management.

Treatments	Plant height (cm) at			
	30 days	45 days	60 days	Harvest
T_0=$N_{150}P_{50}K_{100}$	29.06c	29.06c	36.95c	37.77d
T_1=NPK+Zn_2B_2	31.9 b	31.92b	40.94ab	41.65bc
T_2= NPK +$Zn_2B_2Mo_{0.5}$	32.75ab	32.75ab	39.97b	40.67c
T_3= NPK +$Zn_3B_3Mo_1$	33.38a	33.38a	41.17ab	42.27b
T_4= NPK +$Zn_2B_2Mo_{.5}Mn_4$	33.95a	33.95a	40.97ab	41.90b
T_5= NPK +$Zn_2B_2Cu_1Mo_{0.5}Mn_4$	31.86b	31.86b	42.25a	43.93a
T_6= NPK +$Zn_3B_3Cu_2Mo_1Mn_8$	33.78a	33.78a	40.81ab	41.55bc
LSD (0.05)	1.185	1.185	1.345	1.081
CV (%)	2.46	2.06	1.87	1.47

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 18: Height of carrot plant at 5 growth periods under different nutrient managements.

Treatments	Height (cm) of carrot plant at				
	45 DAS	60 DAS	75 DAS	90 DAS	Harvest
T_0=Control	17.31f	21.54g	29.54g	40.93i	41.66h
T_1=N	19.46cde	26.98f	39.36e	43.41h	44.10g
T_2=NP	20.80bc	29.84d	40.84cd	46.86de	48.32c
T_3=NPK	22.66a	35.85a	45.85a	49.90a	51.08a
T_4=NPKS	20.43bc	29.11de	41.93bc	46.66e	47.33d
T_5=NPKZn	19.66cd	28.34e	39.73de	45.22f	46.37de
T_6=NPKB	20.34bc	29.90d	40.24de	44.78fg	45.67ef
T_7=NPKMo	18.25ef	27.16f	36.97f	45.14f	46.29e
T_8=NPKSZn	18.69de	26.86f	36.30f	43.95gh	44.97fg
T_9=NPKSZnB	20.23bc	30.19cd	40.42cd	47.77cd	49.48b
T_{10}=NPKSZnBMo	21.08b	31.38b	41.38bc	48.40bc	50.23ab
LSD ($P \geq 0.05$)	1.266	1.131	1.042	0.9903	0.9668
CV (%)	3.74	2.30	1.56	1.27	1.21

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 19: Length and diameter of carrot root under different nutrient management.

Treatments	Root length (cm)	Root diameter (cm)
T_0=Control	14.18f	3.49e
T_1=N	14.59de	4.20bc
T_2=NP	15.34c	3.73de
T_3=NPK	16.217a	4.49ab
T_4=NPKS	14.23ef	3.98cd
T_5=NPKZn	15.32c	4.19bc
T_6=NPKB	14.36ef	4.34b
T_7=NPKMo	15.78b	4.34b
T_8=NPKSZn	16.18a	4.23bc
T_9=NPKSZnB	14.48ef	4.30b
T_{10}=NPKSZnBMo	15.69bc	4.66a
LSD ($P \geq 0.05$)	0.3671	0.2782
CV (%)	1.43	3.99

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 20: Height of carrot plant at five growth periods as affected by different micronutrient management.

Treatments	Plant Height (cm) at					
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	Harvest
T_0=Control	17.78 d	24.38 c	34.71c	44.71c	50.47d	52.03d
$T_1=Zn_2B_2$	20.82b	24.85 c	35.18 c	45.18c	51.62cd	53.53 c
$T_2= Zn_2B_2Mo_{0.5}$	18.87c	25.24 c	35.57c	45.57c	51.00cd	52.62cd
$T_3=Zn_3B_3Mo_1$	20.17 b	25.02c	35.35c	45.35c	53.95b	55.72 b
$T_4=Zn_2B_2Mo_{.5}Mn_4$	22.21a	25.60bc	35.93bc	45.93bc	52.50c	53.02cd
$T_5= Zn_2B_2Cu_1Mo_{0.5}Mn_4$	22.54a	28.90a	39.23a	49.23a	58.55a	60.30a
$T_6= Zn_3B_3Cu_2Mo_1Mn_8$	19.07c	26.48b	36.81b	46.8b	52.33c	53.27c
LSD (0.05)	1.028	1.134	1.134	1.134	1.425	1.082
CV (%)	2.86	2.47	1.77	1.38	1.57	1.12

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 21: Number of leaves of carrot plant at different days as affected by different micronutrient management.

Treatments	Number of leaves at					
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	Harvest
T_0=Control	7.25a	7.8ab	8.73bc	9.80d	10.53d	11.67bc
$T_1=Zn_2B_2$	6.91a	7.07b	7.93c	10.27cd	11.07cd	11.87bc
$T_2= Zn_2B_2Mo_{0.5}$	7.27a	8.07ab	9.27ab	11.60ab	11.80bc	12.00bc
$T_3=Zn_3B_3Mo_1$	7.20a	7.73ab	9.33ab	10.80bc	11.20bcd	11.53bc
$T_4=Zn_2B_2Mo_{.5}Mn_4$	7.15a	7.67ab	9.13ab	10.73bc	11.33bcd	11.13c
$T_5= Zn_2B_2Cu_1Mo_{0.5}Mn_4$	7.68a	8.47a	9.93a	12.27a	13.40a	13.80a
$T_6= Zn_3B_3Cu_2Mo_1Mn_8$	7.07a	7.60ab	8.73bc	12.10 a	12.12 b	12.47 b
LSD (0.05)	1.20	1.220	1.017	0.8913	0.9597	1.002
CV (%)	7.25	8.82	6.34	4.52	4.64	4.67

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 22: Diameter and length of carrot root as affected by different micronutrient management.

Treatments	Root diameter (cm)	Root length (cm)
T_0=Control	4.627a	14.00 b
$T_1=Zn_2B_2$	4.120 ab	14.57 ab
$T_2= Zn_2B_2Mo_{0.5}$	4.020 b	14.03 ab
$T_3=Zn_3B_3Mo_1$	4.373 ab	14.62 ab
$T_4=Zn_2B_2Mo_{.5}Mn_4$	4.133 ab	14.49 ab
$T_5= Zn_2B_2Cu_1Mo_{0.5}Mn_4$	4.540 a	15.15 a
$T_6= Zn_3B_3Cu_2Mo_1Mn_8$	3.933 b	14.72 ab
LSD (0.05)	0.4639	1.024
CV (%)	6.15	3.96

In a column, figures having same letters do not differ significantly by DMRT at 5% level.

Appendix 23: Showing the effect of N, NP, NPK, NPKS and NPKZn on the growth of cabbage.

T_0= Control

T_1= N

T_2= NP

T_3= NPK

T_4= NPKS

T_5= NPKZn

T_6= NPKB

T_7= NPKMo

T_8= NPKSZn

T_9= NPKSZnB

T_{10}= NPKSZnBMo

Appendix 26: Effect of different micronutrient on cabbage.

T_0= Control

$T_1= Zn_2B_2$

$T_2= Zn_2B_2Mo_{0.5}$

$T_3= Zn_3B_3Mo_1$

$T_4= Zn_2B_2Mo_{0.5} Mn_4$

$T_5= Zn_2B_2 Cu_1Mo_{0.5} Mn_4$

$T_6= Zn_2B_2 Cu_1Mo_{0.5} Mn_4$

Appendix 25: Showing the effect of doses of Zn, B, Mo, Cu and Mn on the yield of cabbage

T_0= Control

T_1= N

T_2= NP

T_3= NPK

T_4= NPKS

T_5= NPKZn

T_6= NPKB

T_7= NPKMo

T_8= NPKSZn

T_9= NPKSZnB

T_{10}= NPKSZnBMo

Appendix 26: Showing the effect of different micronutrient on cauliflower.

$T_0=N_{150}P_{50}K_{100}$

$T_1=NPK+Zn_2B_2$

$T_2= NPK +Zn_2B_2Mo_{0.5}$

$T_3= NPK +Zn_3B_3Mo_1$

$T_4= NPK +Zn_2B_2Mo_{.5}Mn_4$

$T_5= NPK +Zn_2B_2Cu_1Mo_{0.5}Mn_4$

$T_6= NPK +Zn_3B_3Cu_2Mo_1Mn_8$

Appendix 27: Showing the effect of different nutrient on carrot.

T_1= N

T_2= NP

T_3= NPK

T_4= NPKS

T_5= NPKZn

T_6= NPKB

T_7= NPKMo

T_8= NPKSZn

T_9= NPKSZnB

T_{10}= NPKSZnBMo

Appendix 28: Yield of carrot as affected by different micro-nutrient management

T_0=Control

$T_1=Zn_2B_2$

$T_2= Zn_2B_2Mo_{0.5}$

$T_3=Zn_3B_3Mo_1$

$T_4=Zn_2B_2Mo_{0.5}Mn4$

$T_5= Zn_2B_2Cu_1Mo_{0.5}Mn_4$

$T_6= Zn_3B_3Cu_2Mo_1Mn_8$

Appendix 29: Experimental field of cabbage, cauliflower and carrot.

Cabbage

Cauliflower

Carrot