EFFECT OF ZINC AND BORON ON THE GROWTH AND YIELD OF CAULIFLOWER

ALI AKBER

DEPARTMENT OF HORTICULTURE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

JUNE, 2017

EFFECT OF ZINC AND BORON ON THE GROWTH AND YIELD OF CAULIFLOWER

BY

ALI AKBER

REG. NO. 11-04297

A Thesis
Submitted to the Department of Horticulture,
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfillment of the requirements
for the degree
of

MASTER OF SCIENCE (MS)
IN
HORTICULTURE

SEMESTER: JANUARY- JUNE, 2017

APPROVED BY:

Prof. Dr. Md. Ismail Hossain
Department of Horticulture
SAU, Dhaka-1207.
Supervisor

Prof. Dr. A.F.M. Jamal Uddin
Department of Horticulture
SAU, Dhaka-1207.
Co- supervisor

Prof. Dr. Mohammad Humayun Kabir
Chairman
Examination committee

DEPARTMENT OF HORTICULTURE

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

Ref. No.: **Date:**

CERTIFICATE

*This is to certify that the thesis entitled, **"EFFECT OF ZINC AND BORON ON THE GROWTH AND YIELD OF CAULIFLOWER"** submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTEROF SCIENCE in HORTICULTURE,** embodies the result of a piece of bonafide research work carried out by **ALI AKBER,*** Registration No. ***11-04297** under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2017
Dhaka, Bangladesh

____

Prof. Dr. Md. Ismail Hossain
Department of Horticulture
Sher-e-Bangla Agricultural University
Dhaka-1207
Supervisor

Dedicated To

My Beloved Parents & Respected Research Supervisor

ACKNOWLEDGEMENTS

All commendation, thankfulness and kindness are due to the omniscient, Omnipresent and omnipotent Allah, Who kindly enabled the author to complete this research work successfully.

The author express his deepest sense of gratitude, sincere appreciation and immense indebtness to his supervisor ***Professor Dr. Md. Ismail Hossain,*** *Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, for his guidance, constructive criticism and valuable suggestion in successful completion of the research work and preparation of this thesis.*

The author would like to express his honorable co-supervisor ***Professor Dr. A.F.M. Jamal Uddin,*** *Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, for the scholastic guidance and constant inspiration throughout the research work and preparation of this thesis.*

The author also express his heartfelt thanks to all the teachers of the Departmert of Horticulture, SAU, for their help, valuable suggestions and encouragement during the period of the study.

Finally, The author wishes to acknowledge his heartfelt indebtness and profound respect to his father ***Md. Abdul Aziz*** *and mother* ***Most. Runa Laila*** *for their sacrifice, blessings, patience and encouragement and continuous prays for his success. The author express his sincere appreciation to his brother, sisters, relatives, well- wishers and friends for their inspiration help and encouragement all time.*

The Author

EFFECT OF ZINC AND BORON ON THE GROWTH AND YIELD OF CAULIFLOWER

BY

ALI AKBER

ABSTRACT

A field experiment was conducted at the Horticultural farm, Sher-e-Bangla Agricultural University during October 2016 to February 2017 with two micronutrients viz. Zinc and Boron to investigate the growth, curd size and yield of cauliflower. The experiment was laid out in the Randomized Complete Block Design with three replications. There were four levels of zinc, viz. Zn_0: Control, Zn_1: 1.5 kg Zn ha^{-1}, Zn_2: 2 kg Zn ha^{-1}, Zn_3: 2.5 kg Zn ha^{-1} and four levels of boron, viz. B_0: Control, B_1: 1 kg B ha^{-1}, B_2:1.5 kg B ha^{-1}, B_3: 2 kg B ha^{-1}. Application of zinc resulted the highest plant height, number of leaves per plant, transplanting to curd initiation, transplanting to 50% curd initiation, curd weight with leaves at harvest, curd yield (15.20 ton ha^{-1}) from the Zn_3 treatment. In case of boron application, the highest plant height, number of leaves per plant, transplanting to curd initiation, transplanting to 50% curd initiation, curd weight with leaves at harvest, curd yield (15.30 ton ha^{-1}) from the B_3 treatment while the minimum was recorded from control treatment. For combined application, Zn_3B_3 gave highest curd yield (16.50 ton ha^{-1}) and benefit cost ratio BCR (2.55). From this experiment it can be concluded that Zn_3B_3 treatment combination is suitable dose for higher yield of cauliflower.

CONTENTS

CONTENTS (cont'd)

CONTENTS (cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

ABBREVIATIONS		ELABORATIONS
AEZ	:	Agro-Ecological Zone
ANOVA	:	Analysis of Variance
BARI	:	Bangladesh Agricultural Research Institute
BBS	:	Bangladesh Bureau of Statistics
Cm	:	Centimeter
B	:	Boron
Cu	:	Copper
CV	:	Coefficient of Variation
Df	:	Degree of Freedom
et al.	:	and authors
i.e.	:	That is
Mn	:	Manganese
Mo	:	Molybdenum
MSS	:	Mean Sum of Square
N	:	Nitrogen
pH	:	Potential of hydrogen ion
PPM	:	Parts per million
RCBD	:	Randomized Complete Block Design
SE	:	Standard Error
TSS	:	Total Soluble Solids
RH	:	Relative Humidity
SRDI	:	Soil Resource Development Institute
Zn	:	Zinc
@	:	At the rate

CHAPTER I

INTRODUCTION

Cauliflower (*Brassica oleracea var. botrytis*) belongs to the family Brassicaceae is an economically important winter vegetable crop in Bangladesh. The leading cauliflower producing countries of the world are China, India, France, Italy, Spain, United States of America and United Kingdom (FAO, 2011). It covers about 4% of the total area under vegetables. India comes next to China in cauliflower production (Chadha, 2003). It is nutritionally rich and has medicinal value. It contains good amount of vitamins like riboflavin, thiamine, nicotinic acid and high quality of proteins and minerals like calcium and magnesium. 100 g of edible part of cauliflower (known as Curd) contains 89% moisture, 2.3 g protein, 50 g vitamin C. Vegetable consumption is very low in Bangladesh. Only 32 g vegetables are taken per person per day against the minimum recommended quantity of 200 g per day (FAO, 2014). Cauliflower covered in an area of 40970 hectares with a total production of 211585 metric tons (BBS, 2015). The average yield per hectare of cauliflower is below than its actual yield potentiality.

Cauliflower can be grown in all types of soil with good soil fertility. Most of the micronutrients become in short supply to the crops and some disorder appears resulting in low yields (Joshi, 1997). From production aspect, it requires balanced dose of plant nutrients particularly nitrogen, phosphorus, potassium, molybdenum, zinc and boron (Mengel and Kirby, 1999).

The productivity of cauliflower is not satisfactory due to poor soil fertility and imbalanced fertilization. In the recent past, much emphasis has been given to the use of NPK fertilizers but application of micronutrients especially zinc and boron has been largely neglected. There is great scope for increasing the curd yield per unit area by rational and optimum use of nutrients coupled with better management practices.

Cauliflower is a heavy feeder and it requires large amount of macronutrients as well as micronutrient for better development of curd and its quality (Chhonkar and Jha, 2005). The application of optimum dose of nitrogenous, phosphatic and potassic fertilizers along with some micro-nutrient, viz. zinc, boron and molybdenum are also essential for higher production, better quality and control of nutritional disorders in cauliflower.

Zinc is essential for the growth in human beings, and plants. It is vital to the crop nutrition as required in various enzymatic reactions, metabolic processes, and oxidation reduction reactions. In addition, Zn is also essential for many enzymes which are needed for nitrogen metabolism, energy transfer and protein synthesis. Saini *et al.,* (1985) observed that yields of *Brassica juncea* were increased by zinc application. Plant root absorb zinc as zinc ions, soluble zinc salts and zinc complexes can also enter the plant through leaves. Its deficiency results in shorter internodes, chlorate areas in older leaves or may appear in younger plant too. Banuelos *et al.,* (2000) observed that application of zinc increases yield in rape seed.

Boron is also an essential micronutrient for the growth of plant new cells. Brassica crops in general have a high boron requirement (Xin *et al.,* 1999). In cauliflower, boron deficiency has been reported very frequently (Som *et al.,* 1986). It is relatively non-mobile in plants (Thompson and Troeh, 1957). Its deficiency in plant ceases the terminal bud growth followed by the death of young leaves, browning and bitterness of curd with hollow stem. Similarly, poor root growth, delayed crop maturity and curd quality deterioration are caused by phosphorus and boron deficiency (Mitra, 1990).

Moreover, no research work has been done to determine the effect of boron and zinc on increasing yield in cauliflowers. The present research therefore was conducted to determine the effects of boron and zinc on the nutrition status and increase curd yield.

Objectives:

i) To study the effect of boron and zinc on growth and yield of cauliflower ;
ii) To determine the suitable doses of boron and zinc on growth and yield of cauliflower ; and
iii) To find the proper combinations of boron and zinc for higher yield of cauliflower.

CHAPTER II

REVIEW OF LITERATURE

This chapter deals with the works done by the earlier scientists on the topic **"**Effect of zinc and boron on the growth and yield of cauliflower**"**. Since limited literature is available on the crop selected for the study, the literature pertaining to other crops has also been included and presented below:

Literature on the effect of zinc

Zinc plays an important role in plants metabolic activity of which are related to metabolism of carbohydrates, proteins, phosphates and also of auxins, RNA and ribose functions. (Shkolnik, 1999).

Singh (1990) found best results with regard to plant growth, curd yield and quality of cauliflower. cv. Poushali in pot trials when 2 kg zinc was applied in soils. Soil application of $ZnS0_4$ at 25 or 50 kg ha^{-1} or foliar application at 0.5 per cent or 1.0 per cent to cauliflower crop and found highest yield (17.15 t/ha) with the soil application of zinc at 50 kg/ha as compared to foliar spray or control.

Singh *et al.* (1992) found that application of zinc sulphate at 15 kg/ha and borax at 7 kg/ha significantly increased fruit yield, number of fruits/plant and TSS in tomato.

Baylan *et al.* (1995) conducted a trial on cauliflower with five levels of nitrogen, two levels of phosphorus and four levels of zinc at 0, 10,20 and 30 kg/ha. The number of leaves per plant, leaf area index and marketable yield increased significantly up to 20 kg $ZnS0_4$ /ha. Thereafter, beyond this level yield decreased. Early harvest of curd was obtained at higher level of Zinc (30 kg $ZnS0_4$/ha). Soil application of $ZnS0_4$ at 25 kg/ha increased plant growth, yield, ascorbic acid, TSS, dry matter and sugar in cauliflower.

Phor *et al.* (1995) studied the effect of zinc (0.0, 2.5 or 5.0 kg/ha) on cauliflower and reported that plant growth and yield increased with increasing levels of zinc. The highest yield was obtained by the application of zinc at 5 kg/ha.

Iyengal and Kibe (1998) observed in an experiment on cauliflower that application of $ZnSO_4$ 20 kg/ha increased the curd size index (189 cm^2) and marketable yield (20.1 ton/ha) significantly. There was increase in protein content and dry matter percentage with increasing levels of Zn, while the highest ascorbic acid content was recorded by application with 20-25 kg zinc.

Pandey and Sinha (1999) opined that soil application of $ZnSO_4$ @ 25 kg/ha significantly increased the yield of cauliflower cv. Hissar-1. Earliness in curd initiation and maturity might be due to physiological role of zinc and rapid translocation of photosynthesis towards the curd which might have develope advance curd.

Salim *et al.* (2000) reported that both Zn and Cu ion had an inhibitory effect on the growth of spinach, cauliflower and parsley. Maximum reduction in time from transplanting to initiation of curd and minimum days to curd maturity was recorded in 2-2.5 kg zinc treatment.

Nayak and Nandi (2000) revealed that yield (431.55 q/ha), head weight (1.50 kg), net income (Rs. 39,099/ha) and benefit cost ratio (1.83) were the highest with 25 kg $ZnSO_4$ sprayed thrice at 10 days intervals.

Bhagavatagoudra and Rokhade (2001) stated that application of 40kg Zn/ha gave maximum curd yield of 45.74 t ha^{-1} followed by 20 kg Zn/ha (39.74 t ha^{-1}) and control (36.13 t ha^{-1}), accounting for 26.20 and 9.99% increase in yield over control. This may be attributed to significantly greater weight (772.38 g), surface area (7.914 cm^2) and diameter (13.80 cm) of curd compared to the control treatment respectively and higher benefit cost ratio (2.95) with Zn at 40 kg/ha followed by 20 kg Zn/ha (3.8) and control (1.64).

Parekh *et al.* (2003) lead a field experiment and observed that significantly highest diameter of curd (17.82 cm), volume of curd (1173.45 cm^3) and yield 17.32 ton/ha were recorded with combine sprays of zinc ($ZnSO_4$) and iron ($FeSO_4$) at 0.5% concentration each.

Divrikli *et al.* (2003) reported that zinc treatments had significant effect on reducing time for initiation and maturity of curd. The field experiment indicated that application of zinc (20 or more than 20 kg/ha) is necessary for better qualitative and quantitative production of cauliflower variety.

Shumiati (2003) lead a field experiment on the effect of nitrogen and zinc on harvesting time and yield of Cauliflower cv. Cirateun and showed that Cauliflowers fertilized with ammonium nitrate combined with $ZnSO_4$ gave the highest yield of 16.43 t/ha. Yields in kg per plant were 0.488, 0.492, 0.386 and 0.412 and curd diameters were 13.8, 13.9, 12.2 and 12.1 cm for the 4 treatments, respectively.

Balyan *et al.* (2004) applied N (0, 60, 120 and 180 kg) and Zn (0, 2.1, 4.2 and 6.3 kg) and found that marketable curd and yield of cauliflower increased with increasing levels of Zn to maximum (198.57 q/ha) at 4.2 kg/ha Zn and then decreased.

Singh and Singh (2004) observed that foliar application of Zn at 30 ppm produced maximum plant height and plant spread in cauliflower cv. snowball-16. The highest net return (Rs. 52628.30/ha) and cost benefit ratio (1:2.8) were recorded for 1.0% N + 30 ppm Zn followed by 1.0% N + 0 ppm Zn.

Chhipa (2005) observed the significant increase in plant height, plant spread and number of leaves per plant at different growth stages with the application of 40 kg S/ha and 4 kg Zn/ha in cauliflower cv. RC Job-1.

Duraisami and Sakal (2005) recorded highest curd diameter (19.3 cm), curd weight (777g) and curd yield (18.79 t ha^{-1}) of cauliflower with the application of 1 kg B/ha+ 2.5 kg Zn/ha.

Bijarnia (2007) recorded maximum curd yield (277 to 460 q/ha) in cauliflower cv. snowball-16 with 25 kg $ZnSO_4$/ha and stated that application of micronutrients to sustain soil health and crop productivity besides maintaining the quality of vegetables is of profound importance.

Andrejiova *et al.* (2011)reported from an experiment that application of Sulphur 100 kg/ha+ Zinc 2.5 kg/ha provided the most beneficial impact on yield quantity, sulforaphane, vitamin C, and nitrate contents in *Brassica campestris*.

Kotecha *et al.* (2011) observed in a field experiment that ($ZnSO_4$ 0.5% + GA_3 100 ppm) recorded significantly highest plant height (15.85 cm), stem girth (7.37cm), leaf area (385.93 cm^2), curd diameter (16.85 cm), curd volume (1089.17 cm^3), average curd weight (1018.33 g), cauliflower curd yield (30.48 t/ha). Other morphological parameter viz., plant spread, number of leaves per plant, days taken to head formation remained unaffected by the different levels micronutrients and growth regulators over control.

Zubair *et al.* (2011) conducted an experiment on interactive effects of nitrogen and zinc on growth and yield of cauliflower. Four levels of nitrogen (0, 100, 150 and 200 kg/ha) and three levels of zinc (0, 2 and 5 kg/ha) were applied. Total yield (21.34 ton/ha) was increased 100% as compared to control (10.50 ton/ha) when plots received nitrogen at 150 kg/ha and zinc at 2 kg/ha.

Praveen *et al.* (2016) reported that application of micronutrients $ZnSO_4$ (0.5 percent) + $FeSO_4$ (0.5 percent) at 30, 45 and 60 days after sowing along with a recommended dose of NPK (60+60+60 kg/ha) and FYM 20 ton/ha to the cauliflower cv. Snowball were the most beneficial treatment for getting higher vegetative growth and yield (21-24 ton ha^{-1}).

Literature on the effect of boron

Boron is an important nutrient for all plants. It plays an important role in plants physiological activity like as cell division, elongation and enlargement of cell, tissue respiration, curd development, sugar transport, hormonal growth, cytokynin synthesis (Lewis, 2000).

Kotur (1991) reported that the application of boron @ 1.5 kg/ha in conjunction with lime produced high curd yield and corrected the boron deficiency for three successive crops.

Kotur (1992) observed that application of boron significantly increased curd yield at up to 15 kg/ha with 1.5 kg B/ha, the yield from the RWR sequence was 84% higher than the control whereas the field from the RWR sequence was 65% higher than the control.

Rahman *et al.* (1992) reported that application of boron (1kg/ha) in combination with sulfur (40 kg/ha) and molybdenum (1 kg/ha) significantly increased curd yield (20 ton/ha) and seed yield (250 kg/ha) and lower values were recorded with no application of boron, sulfur and Mo in cauliflower.

Mehrotra and Mishra (1994) found that cauliflower grown in sand culture was the best when sprayed with boron solution. Further in their studies noted the highest plant height, maximum number of leaves/plant and maximum stem diameter in cauliflower with the application of 1.5 kg boron. The cauliflower plant attained maximum plant height with the application of boron (2.5 kg/ha) in the form of borax.

Singal and Gautam (1995) opined that weight of trimmed head and yield of cauliflower significantly increased with the application of boric acid. The increased curd weight and advancement in curd initiation with the application of 0.5% boric acid in cauliflower and broccoli were observed by a number of workers.

Shen *et al.* (1996) studied that the young cauliflower plants grown in nutrient solution and soil culture at different levels of boron. Growth was abnormal and plant dry weight reduced under both deficient and excess B levels. Proteolytic enzyme activity in leaves was reduced by deficient (0.1) mg/litre or mg/kg soil or excess (20 mg/litre or 10 mg/kg soil) B levels.

Batal and Mullinix (1997) increasing boron level from 2.2 kg to 8.8 kg/ha reduced hollow stem but had no effect on yield or curd mass in clay soil. On sandy loam soil, B at 4.4 kg/ha maximized yield and curd mass, but the hollow stem disorder continued to decrease as B rate were increased from 2.2 kg to 8.8 kg/ha.

Ghosh and Hasan (1997) applied borax (0, 10, 15 and 20 kg/ha) as soil application in cauliflower and found increased leaf number, curd size, curd weight and curd yield per hectare up to 15 kg borax/ha. The highest yield (524.00 q/ha) was obtained in 15 kg borax/ha as compared to control (463.00 q/ha).

Kotur (1997) reported that increasing level of B (0, 0.0125% and 0.125%) as boric acid with 80 kg N/ha, each applied thrice by foliar spray, significantly increased curd size and yield of cauliflower.

Kotur (1998) while working with cauliflower and reported that yield of marketable curd increased from 0.4 tons/ha in control to 9.4 tons/ha at 1.6 kg B/ha and thereafter the curd yield was decreased with higher doses of boron.

Mukhopadhayay and Chattopadhayay (1999) reported that soil application of borax at 15, 18 and 20 kg/ha progressively increased growths and yield of cauliflower. The biggest level gave the greatest yield of curds over control.

Prabha and Ranjan (1999) observed in an experiment to study the method of application of boron on cauliflower, broccoli, tomato etc. The B concentration of the cole crops were distincted by the treatments. The application of borax generally 15-20 kg/ha increased the dry weight of shoots at both flowering and harvest stages.

Adhikari *et al.* (2001) stated that plant growth (plant height, leaf number, leaf length and biomass production) were observed to be affected by the different boron levels applied to the cauliflower plants. Maximum biomass (1061.45 g/ plant) was produced when the crop was fertilized with 25 kg borax/ha and 10.92 t/ ha of curds was produced when the crop was supplied with 25 kg of borax/ha which is 403.7% higher than the control plot (2.7 t/ha).

Ghimire (2001) reported that the highest yield (15.45 ton/ha) was obtained when the crop was supplied with 22.5 kg borax per hectare. He further reported that boron and molybdenum increased the curd size and weight.

Rafique *et al.* (2001) reported that yield increase in *Brassica oleracea* (43%) was given by 1 mg B while in *Brassica juncea* the highest increase of 36% was given by 1.5 mg B. Due to deficiency of B gave stunted growth and deformed leaves.

Sharma (2002) conducted an experiment with cauliflower and reported that maximum plant height, curd yield (9.80 q/ha), curd weight were obtained when 25 kg borax/ha was applied. Similarly, the highest values for all these characters were obtained at 1.5 kg ammonium molybdate.

Malewar (2003) opined that application of B, Mo to soils with low to marginal content of available B caused 40-45 per cent increase in curd yield of cauliflower over control. The critical B concentrations established for cauliflower by graphical and statistical procedures were 0.52 and 0.51 mg/kg, respectively. The combined application of B and Mo to soil synergistically increased curd yield by 12 per cent and 17 per cent compared with single application of B and Mo, respectively. He also observed that lime application to soil along with 1 kg boric acid and 0.1 per cent ammonium molybdate resulted in higher curd yields and net returns when compared to the control.

Singh *et al.* (2003) conducted studies on the response of cauliflower to borax application in laterite soils and the results indicated that application of borax @ 5 kg/ha in addition to 0.25 per cent foliar spray at 45 and 60 days after planting significantly increased curd weight and curd width, and registered the highest curd yield.

Kibria *et al.* (2004) conducted an experiment at the Agricultural Research Station, Raikhali, Rangamati Hill District during the winter (rabi) seasons of 2004-05 to find out the suitable doses of B and N for higher yield and good quality head of broccoli. Boron application increased plant height, number of leaves per plant, length and width of the leaf, plant spread, main head weight and head yield both per plant and per hectare significantly up to 1.5 kg/ha B with 120 kg Urea.

Khadka *et al.* (2004) observed the better yield of cauliflower curd (14.37 and 13.90 t/ha) from the treatment with 20-kg borax in both the years 2001 and 2002 respectively. Similarly, the higher amount of soil (0.730 and 0.768 ppm B) also extracted in the same treatment as a residual after harvest of cauliflower.

Pizetta *et al.*(2005) reported that the yield intervals obtained with broccoli, cauliflower and cabbage varied according to the following intervals: 16.9 to 20.5 t/ha, 21.6 to 29.6 t/ha and 40.5 to 46.3 t/ha, respectively. The increase in production observed in broccoli and cabbage yield was linear with boron levels and the boron effect on cauliflower yield was quadratic. For maximum cauliflower yield (30 t/ha) apply 5.1 kg/ha of B. Broccoli and cabbage were less sensible than cauliflower to boron deficiency and toxicity. Quality of the curds decreased when 2 kg/ha or 6 kg/ha B were applied in cauliflower fertilization.

Sarma and Pandita (2005) documented that application of 0.5% borax recorded the highest yield and harvest index of cauliflower and cabbage. The highest quality of protein and ascorbic acid content were found by same concentration of borax.

Waring and Theiler (2003) recorded that increase in curd size and found helpful in increasing curd weight with the application of boron. Maximum curd sizes of cauliflower were recorded with the soil application of boron at 10 kg/ha.

Shukla *et al.* (2003) opined that application of boron, to soils with low to marginal content of available B caused 45-50 per cent increase in curd yield of cauliflower over control. The critical B concentrations established for cauliflower by graphical and statistical procedures were 0.52 and 0.51 mg/kg, respectively. The combined application of B and Mo to soil synergistically increased curd yield by 15 per cent and 20 per cent compared with single application of B and Mo, respectively. He also observed that lime application to soil along with 1.5 kg boric acid and 0.15 per cent ammonium molybdate resulted in higher curd yields and net returns when compared to the control.

Dixit and Islam (2006) found in an experiment with cauliflower cv. ‘Parijat’ that B application 1.5-2 kg/ha increased cauliflower yield by 7-8%. Synergistic interaction could be obtained by applying boron within soil and plant system.

Ahmed (2007) conducted an experiment on cauliflower and reported that applying boron (15 kg/ha) gave the highest stalk length while the highest curd diameter, curd weight and compact curd quality was obtained with boron, zinc, manganese and copper combination of fertilizer.

Moniruzzaman *et al.* (2007) reported that boron application significantly increased plant height, number of leaves per plant, length and width of the leaf, plant spread, main curd weight and curd yield per plant and per hectare up to 1.5 kg B/ha in cauliflower and broccoli.

Alam and Jahan (2007) studied and observed that growth, yield and other yield contributing characters of cauliflower significantly affected by boron levels. Application of 3-4 kg B/ha (0.45-0.60 g boric acid/pot) is suitable in cauliflower or any upland vegetable crop production for better growth and yield in calcareous soils, but above 4.0 kg B/ha it may be harmful for crop growth and yield. The results also indicated that cauliflower can be grown successfully in pot-soil for commercial production in green house with proper fertilization specially boron.

Nayanmoni *et al.* (2007) revealed that the growth attributes of cauliflower cv. Pusakatki were influenced by different level of boron significantly. The maximum numbers of primary branches, length of siliqua and seed yield were recorded with 10 kg borax per hectare.

Prasad and Rai (2008) reported that under boron application Pusa Snowball gave the highest yield (15.4 t/ha) followed by Sel-5 (14.7 t/ha) with lowest yield observed in K-19 (8.8 t/ha). Application of boron at 5 kg/ha with 2.5-3 kg ammonium molybdate significantly increased the yield up to 133% curd weight, curd diameter, number of marketable curds and total plant height

Saha *et al.* (2010) also conducted an experiment to study the effect of boron on cauliflower with spraying of borax viz. control, 0.3 percent at 45 days after transplanting (DAT) and 0.3 percent at 30 & 45 DAT). The results revealed significant response on growth and quality of sprouting cauliflower for different treatments. Spraying of borax @ 0.3 percent at 30 + 45 DAT gave maximum protein content of curd (3.24 g/100 g).

Singh *et al.* (2011) observed that the maximum value of the characters viz. plant weight (1439.30 g), curd weight (758.70 g), plant height (63.98 cm) and number of leaves (16.25), were recorded in the plots receiving boron @1.50 kg/ha & boron application with broadcast in two doses over control.

Ramchandra (2011) reported that boron deficiency in cauliflower and mustard decreased dry matter yield. Due to low sufficiency of B plant had low water potential, stomatal pore opening and transpiration, decreased chlorophyll concentration, inter-cellular concentration and photosynthesis but there is an increase in accumulation of soluble nitrogen, protein and starch content.

Farag *et al.* (2012) evaluated that among all the treatments combinations treatment (Boron 20 kg + sodium molybdate 2 kg/ha) and treatment T_4 (Boron, 100ppm + molybdenum, 50ppm) gave best performance when applied basic application and foliar application, respectively. Observations were recorded on different characters viz. plant height (62.87 cm), number of leaves/plant (25.23), fresh weight of leaves/ plant (2.21 kg), length of leaves (19.95 cm), width of leaves (9.45 cm), total weight of plant (2.12 kg), days taken to curd maturity (43.48 days), diameter of curd (20.78 cm) and curd yield up to 28 ton ha^{-1}.

Hussain *et al.* (2012) conducted an experiment on cauliflower and broccoli where a combined application of 180 kg N with 1.0 kg B (/ha) has been found suitable for achieving higher yield of quality broccoli. Therefore, the combined dose of 180 kg N and 1.0 kg B/ha could be considered for achieving the maximum yield of quality cauliflower in Shallow-Red-Brown Terrace Soil of Madhupur Tract.

Kumar and Malabasari (2012) carried out an field experiment during 2007 to study the effects of boron rates, its sources and organic manures on autumn cauliflower and observed curd yield, quality, boron uptake, its availability and balance and net income increased due to use of boron level of 1.5 Kg/ha.

Raghubanshi *et al.* (2013) observed that application of borax 20 kg/ha and sodium molybdate 2 kg/ha as soil application in combination of recommended dose of NPK

@ 120: 60:60 kg/ha gave the maximum height of the plant, length of leaf, width of leaf, total weight of plant, width of curd, average weight of curd and curd yield.

Devi and Prasad (2012) conducted an experiment on the effects of application of borax (1 kg/ha) solution on cauliflower and found significant increase in plant height, number of leaves, shoot fresh weight, dry weight, root fresh weight, dry weight and yield.

Zhu *et al.* (2013) reported that B deficiency seriously affected in growth, floral development and yield specially curd initiation and curd quality in cauliflower, rapeseed etc. The abnormalities observed included browning of curd due to deficiency of boron in soil. In serious cases stem becomes hollow with water soaked tissues. In advanced stage pinkish or brown area develop on surface of the curd. This can be controlled by applying sodium borax 20 kg/ ha or spraying of boron 0.25 to 0.50 % solution.

Randhawa and Bhail (2013) concluded that under favorable agro-climatic conditions, the application of 18 kg borax and 1.8 kg ammonium molybdate per ha was found beneficial for growth, yield, and quality of cauliflower.

Batabyal *et al.* (2015) investigated that Boron application significantly increased cauliflower yield, plant B concentration and uptake of B. The critical plant B concentrations for deficiency, sufficiency and toxicity varied with the growth stages and the values being (26, 31 and 48 mg/kg) at 50 days of growth and (17, 24 and 35.5 mg/kg) at harvest, respectively. The study also recommends application of fertilizer B at the rate 0.9–4.5 kg ha^{-1} for optimum B nutrition to cauliflower in Inceptisols of the Gangetic plains of India.

Swain *et al.* (2015) conducted an experiment and found that application of micronutrients (boron fertilizers) controls all the physiological activities which helps the maximum fruit yield. Application of borax (1.5-4.0 kg ha^{-1}) gave significantly larger and heavier fruits and significantly higher curd yield than the other treatments.

Literature on the effect of zinc and boron

Singh *et al.* (1994) applied zinc (0, 2.1, 4.2 or 6.3 kg/ha) and boron (0, 1, 1.5, 2 kg/ha) found that curd yield increases up to 367.53 q/ha as compared to control and also crude protein per cent increased with increasing level of zinc in cauliflower.

Srihari and Tiwari (1997) applied Zn and B at 10 or 20 kg/ha alone or in combination and obtained highest mean plant height (59.35 cm), number of leaves (12.53) and yield (69 q/ha) in cauliflower when both the elements were applied at highest rate. The control yield was 28.3 q/ha.

Mukhopadhaya and Jana (2002) conducted in an experiment on the effect of boron, zinc and molybdenum on curd yield and quality of cauliflower. They reported that higher curd yield and seed quality was observed by the application of boron as a borax at the rate of 20 kg/ha, 25-40 kg $ZnSO_4$ and 1.5- 2 kg ammonium molybdate as compared to control. The combined effect of these micronutrients showed significant increase in curd yield up to 504.81 q/ha.

Ali and Sur (2003) reported that application of boron and zinc expressively increased yield of broccoli, cauliflower and mustard. 25-37.5 kg/ha $ZnSO_4$ and 10-15 kg borax/ha were recommended for economic return.

Verma *et al.* (2003) investigated in some experiments during the rabi seasons of 1999 at Jabalpur, Madhya Pradesh, India to find out the effect of zinc and boron on the growth and yield of cauliflower cv. Cheddar. Application of 15kg $ZnSO_4$+ 2 kg B/ha gives the higher yield.

Varghese and Annie (2005) carried out an experiment on cauliflower and stated that application of 1.0 kg B/ha with 2.5 kg Zn/ha was found to be better than individual application of various levels of B and Zn and any other combinations of these two elements in terms of nutrient uptake and soil fertility.

Zhang (2006) reported that applications of Zn and B micronutrient fertilizers could obviously increase yield and improve quality of cauliflower. The effect of the combined application of Zn and B (Zn 2.25 + B 1.50) kg/ha on cauliflower was the best. Its production-increasing ratio had reached to 32.2 per cent. It was clear that the B fertilization had better effect than the Zn fertilization on yield because the production-increasing ratio of B fertilization was 16.1 per cent higher than Zn fertilization.

Maurya *et al.* (2006) a field experiment were observed on foliar application of different concentrations of Zn, B and Mo (in various combinations or separately) increased the average FW and DW of leaves and curd, and the yield. In addition to that the individual treatments Zn_3 was the best for vegetative growth and B, followed by Mo for curd growth and yield. A combination of 40ppm Zn, 0.4% B and 0.2% Mo gave the best result for all growth and yield parameters.

Pardeep *et al.* (2006) reported that cauliflower grown in the rabi seasons was given recommended NPK fertilizer+10 0r 20 kg Zn/ha, 5kg B/ha which helps in curd formation, curd yield. In another experiment they also added that 1.3 kg boron with 60 kg P_2O_5/ha is optimum for cauliflower production.

Agarwal and Ahmed (2007) opined that highest curd diameter; curd weight and curd quality was obtained with combined application of boron (1.5 kg/ha) and zinc (2.5-4 kg/ha).

Nahar *et al.* (2008) investigated that application of different micronutrients ((N, P, K, S, Zn, B and Mo at 150, 50, 100, 20, 3, 3 and 1 kg/ha respectively exhibited significant influence on the growth and yield of cabbage. The highest plant spread (70.76 cm), height (37.89 cm), leaf length (37.83 cm), leaf breadth (27.13 cm), head thickness (12.85 cm), head diameter (23.02 cm), marketable head yield (76.53 t/ha) which is 191% increase over control), early curd/head formation and maturity were recorded from the plot receiving B at the rate of 3 kg/ha respectively.

Kuldeep *et al.* (2011) carried out an experiment and observed that (B 2 kg/ha+ Mn 2.5 kg/ha + Zn 3 kg/ha) was found to be the best treatment combinations to obtain the higher growth, yield, and curd quality in cauliflower.

Kant *et al.* (2013) found that the plant height, number of leaves per plant, biological yield, curd weight and marketable yield were found highest with combined soil application of 20 kg $ZnSO_4$ + 10kg B/ha. The increase in the curd yield by the application of these micronutrients may be attributed to their role in enhancing the translocation of carbohydrates from the site of their synthesis to the storage tissue in the curd.

Rajawat *et al.* (2014) conducted a field experiment and reported that the micronutrients (B, Mo, Mn and Zn) were applied at the rate of 2 kg (B), 0.5 kg (Mo), 2.5 kg (Mn), 3 kg (Zn) per hectare significantly increased the plant height (51.30 cm), number of leaves(22.92), plant spread (52.83 cm), diameter of curd or head (16.90 cm), average curd or bud weight of per plant (303.69gm), yield/ha(121.48q), vitamin-C (93.92 mg), TSS Brix (8.37) content, plant fresh weight (908.28gm), dry plant matter(95.61gm), root weight (45.02gm) and dry weight(11.65gm) were maximum.

Shalaby *et al.* (2014) reported that the application of urea 60 kg/ha with boron (2.5 kg borax/feeder) or zinc (5-6 kg $ZnSO_4$/feeder) to cauliflower plants of the cultivars 'Soltany' and 'Amsheery' significantly enhanced curd yield and quality in both cultivars (1 feeder=0.42ha).

Moklikar *et al.* (2015) reported from a field experiment that the maximum yield (34.80 kg/ha) was observed by the foliar application of $FeSO_4$0.5% + Borax Spray 0.2% + $ZnSO_4$0.5% Spray. The total soluble solid and ascorbic acid was significantly influenced by the foliar application of micronutrients. The maximum T.S.S. (6.80 Brix) was observed by the foliar application of Borax Spray 0.2% + $ZnSO_4$ 0.5% Spray and ascorbic acid (65.96 mg/100g) was observed by the foliar application of $FeSO_4$ 0.5% + Borax Spray 0.2% + $ZnSO_4$ 0.5% Spray.

Chaudhary and Mukharjee (2016) concluded that for getting higher yield of cauliflower curd (Zn-40 kg/ha, Cu-3 kg/ha and B-5 kg/ha) is favorably influenced plant growth and yield attributes. Two spray of micronutrients at 45 days after transplanting and 60 days after transplanting was found better and yield up to 40 ton/ha.

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental Site

The field experiment was conducted at the Horticulture farm of Sher-e- Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from October, 2016 to February, 2017. The experimental site was proceeding accustomed as vegetable garden and recently developed for research work. The location of the site in 23°46' N latitude and 90°23' E longitude with an elevation of 8.24 meter from sea level.

3.2 Climate

The climate of the experimental site is subtropical, characterized by heavy rainfall for the time it lasts the months from April to September (Kharif season). Information considering average monthly temperature as recorded by Bangladesh Meteorological Department (climate division) during the period of study has been presented in Appendix I.

3.3 Soil

The morphological characters of soil of the experimental plots are belonging to Tejgaon series. The soil of the experimental area belongs to the Modhupur Tract (AEZ No. 28) with 5.8-6.5, ECE-25.28 (Haider, 1991).The analytical data of the soil sample collected from the experimental area were determined in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix II.

3.4 Land preparation

The experimental plot was first cultivated by a tractor on October 2016. It was prepared by ploughing, cross ploughing followed by laddering. Then the land was leveled and the corners of the experimental plots were spaded and clods were broken down into pieces. The weed was removed from the field and the land was finally prepared. The soil was treated with soil insecticide Furadan 5G to protect the young plants from the attack of soil insect such as cut worm, mole cricket and field cricket.

3.5 Plant Materials

The experimental material is the seed of cauliflower cultivar F_1 hybrid variety was used in the experiment and sown in 23 October 2016.

3.6 Treatment of the experiment

The experiment was conducted to study the effects of zinc and boron on growth and curd yield of cauliflower. The experiment consisted of two factors were as follows:

Factor A: Four levels of zinc

Zn_0 = Control

Zn_1 = 1.5 kg zinc ha^{-1}

Zn_2 = 2 kg zinc ha^{-1}

Zn_3 = 2.5 kg zinc ha^{-1}

Factor B: Four levels of boron

B_0 = Control

B_1 = 1 kg boron ha^{-1}

B_2 = 1.5 kg boron ha^{-1}

B_3 = 2 kg boron ha^{-1}

There were altogether 16 treatments combination thus planned as following:

Zn_0B_0, Zn_0B_1, Zn_0B_2, Zn_0B_3, Zn_1B_0, Zn_1B_1, Zn_1B_2, Zn_1B_3, Zn_2B_0, Zn_2B_1, Zn_2B_2, Zn_2B_3, Zn_3B_0, Zn_3B_1, Zn_3B_2, Zn_3B_3.

3.7 Design and layout of experiment

The two factors experiment was laid out following Randomized Complete Block Design (RCBD) with three replications. The area was divided into three equal blocks. Each block was divided into 16 plots where 16 treatments were allotted at random. Thus there were 48 unit plots altogether in the experiment. The size of each plot was 1.80 m × 1.35 m. Thirty day old seedlings were transplanted in the main field on 10 November 2016 following 60 x 45 cm spacing. A layout of the experiment has been shown in figure 1.

3.8 Manuring and fertilization

Fertilizers were applied at the rate of 10 ton cowdung, 240 kg urea, 150 kg TSP, 220 kg MP per hectare. Cowdung, TSP, 50% MP and total amount of micronutrients (Zn, B) according to experiment were applied during final land preparation. Urea and the rest MP were applied as top dressing in three installments at 15, 30 and 45 days after transplanting (BARC, 2006).

3.9 Raising of seedling

Seedlings were raised in seedbeds of 3 m × 1 m size prepared on high land under the polythene tunnel at Horticulture farm. The seeds were sown in the seedbed on 23 October in 2016. After seed sowing the soil surface of the seedbed slightly compacted by hand. Furadan 5G was dusted on the seedbed as a precaution against ants and cutworms. The seedlings were raised with proper care.

3.10 Transplanting of seedlings

Small pits were prepared by removing the soil and seedlings were placed in the pits followed by compaction of soil. Healthy, diseases free and uniform sized 30 days aged seedlings were transplanted in the experimental plots on 25 November, 2016 at a spacing of 60cm x 45 cm. Newly transplanted seedlings were watered by a watering cane. The transplanted seedlings were shaded for three days with banana leaf sheath cuttings. The plants were irrigated every evening until they were fully established.

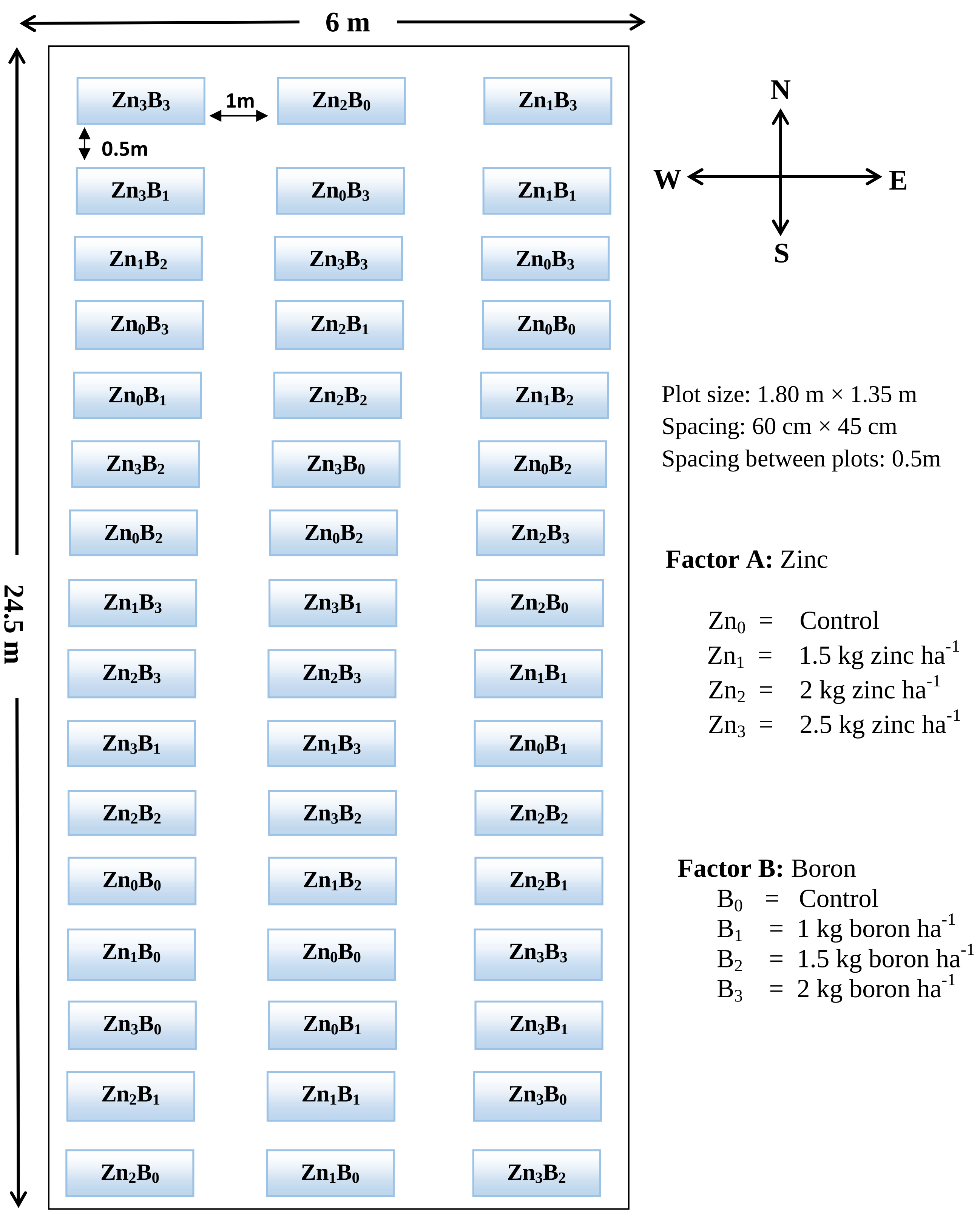

Fig. 1 Field layout of the experimental plot

3.11 Intercultural operation

After transplanting of seedlings, various intercultural operations like as weeding, spading, irrigation etc. were performed better growth and development of cauliflower seedlings.

3.11.1 Weeding

Weeding was done from time to time during the experimental period to keep the plots free from weeds. First weeding was done 30 days after transplanting.

3.11.2 Spading and mulching

Spading and mulching were done to break the soil crusts as and when required specially after irrigation when soil became dry.

3.11.3 Irrigation

Irrigation was done time to time during the crop period. The young plants were irrigated by watering cane. As the plant grew older, irrigation was applied by the flood method.

3.12 Harvesting of Cauliflower

The best stage of maturity is determined by curd size and condition. Local growers usually harvest the head upon the desired size and before the curds become discolored, loose or otherwise blemished. The head should be compact and not to be broken into segments. Over mature head becomes long, flower stalks elongates resulting in loose, leafy condition and possess poor market value. The curds are cut off the stalk with large sharp knife.

3.13 Data collection

During the present study data in respect of the following characters were collected and the procedure for data collection for different characters is given below:

3.13.1 Plant height

The height was measured in each plot from the ground to tip of plant at 30 DAT, 50 DAT and harvesting stage from five randomly selected plant and average was calculated and expressed in cm.

3.13.2 Number of leaves per plant

The number of leaves per plant was counted at 30 DAT and harvesting stage from five randomly selected plants from each plot and average was calculated.

3.13.3 Leaf length

Length of the leaf was measured in each plot with the help of scale and expressed in centimeter (cm).

3.13.4 Leaf breadth

Breadth of the leaf was measured in each plot with the help of scale and expressed in centimeter (cm).

3.13.5 Leaf area

The leaf area was recorded from five randomly selected plants from each plot on the basis of leaf length and breadth in square centimeter (cm^2).

3.13.6 Days from transplanting to curd initiation

Days required for curd initiation from transplanting was recorded from first curd initiation.

3.13.7 Days from transplanting to 50 % curd initiation

Days required from transplanting to 50 % curd initiation was recorded when 50 % of the plants were started to form curd.

3.13.8 Days from curd initiation to harvest

Days required for curd initiation to harvest was recorded from five randomly selected plants in each plots and average was calculated.

3.13.9 Length of the biggest leaf at harvest

The length of the biggest leaf was measured at the time of harvest with the help of a measuring scale and it was expressed in centimeter.

3.13.10 Breadth of the biggest leaf at harvest

The breadth of the biggest leaves was recorded at the time of harvest by a measuring scale and expressed in centimeter.

3.13.11 Curd diameter at harvest

Curd diameter was measured with a measuring scale placing it vertically at the widest point of the curd and was expressed in centimeter.

3.13.12 Curd weight with leaves at harvest

The curd weight with leaves was recorded with the help of a weighting balance just after maturity of the curd. It was expressed in kilogram (kg).

3.13.13 Pure curd weight

Average curd weight of five randomly selected plants was calculated in each plot wise.

3.13.14 Curd yield plot^{-1}

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

3.13.15 Curd yield ha^{-1}

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

3.14 Statistical analysis

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

CHAPTER IV

RESULTS AND DISCUSSION

Results of the investigation entitled "Effect of zinc and boron on growth and yield of cauliflower (*Brassica oleracea*) are elaborately presented in this chapter. Observations related on growth, yield attributing parameters and yield were statistically analyzed and each character is described using of tables and graphical illustration to make the results more clear, understandable and meaningful.

4.1 Plant height

In case of zinc application significant difference was observed at 30, 50 and harvest DAT (Appendix III). At 30, 50 and harvest DAT the maximum plant height (14.70 cm, 25.03 cm and 42.13 cm) was obtained from Zn_3 (Fig. 2) due to application of different levels of zinc. On the other hand, at 30, 50 and harvest DAT (11.20 cm, 20.86 cm and 37.03 cm) was recorded from Zn_0 (control) treatment. Mokhlikar *et al.* (2015) stated that plant height increased gradually at the early stages and decreased at the later stages of the plant growth due to micronutrient.

The plant height was also varied significantly due to different levels of boron application (Appendix III). During the period of plant growth the highest plant height at 30, 50 and harvest DAT (14.28 cm, 23.51 cm and 41.66 cm) was observed in B_3 (2 kg ha^{-1}) treatment. On the other hand, at 30, 50 and harvest DAT the lowest plant height (12.97 22.36 and 39.94 cm) was recorded from B_0 (control) treatment (Fig.3). The results support to those of Ghimire (2001).

The plant height significantly influenced by the interaction effect of zinc and boron application (Appendix III). At 30, 50 and harvest DAT the highest plant height (16.82 cm, 26.02 cm and 44.50 cm) was recorded from the treatment combination of Zn_3B_3 (2.5 kg zinc ha^{-1} and 2 kg boron ha^{-1}).

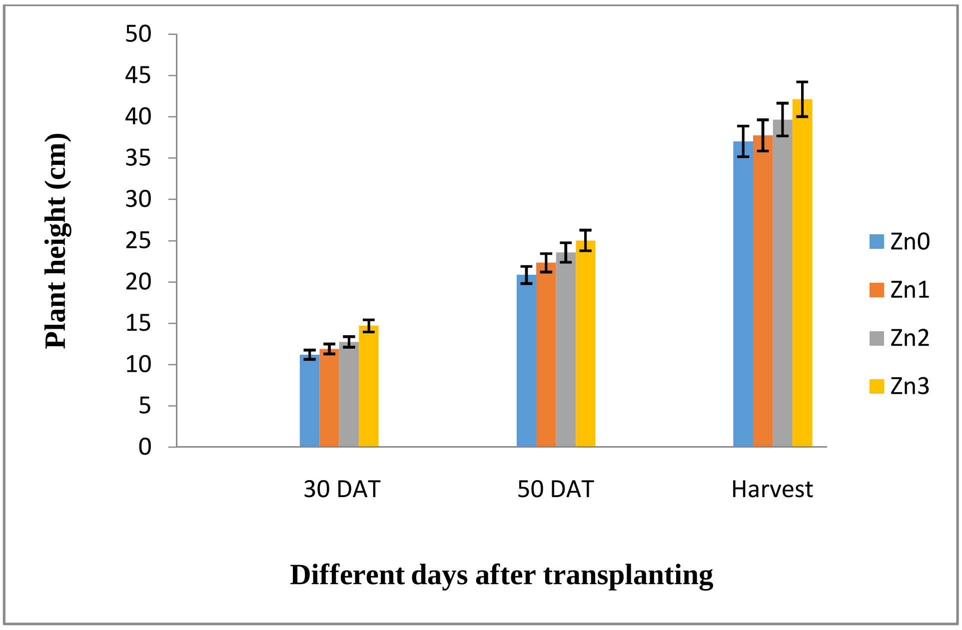

Fig. 2. Effect of zinc on plant height of cauliflower

Zn_0: Control, Zn_1:1.5 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}, Zn_3: 2.5 kg zinc ha^{-1}

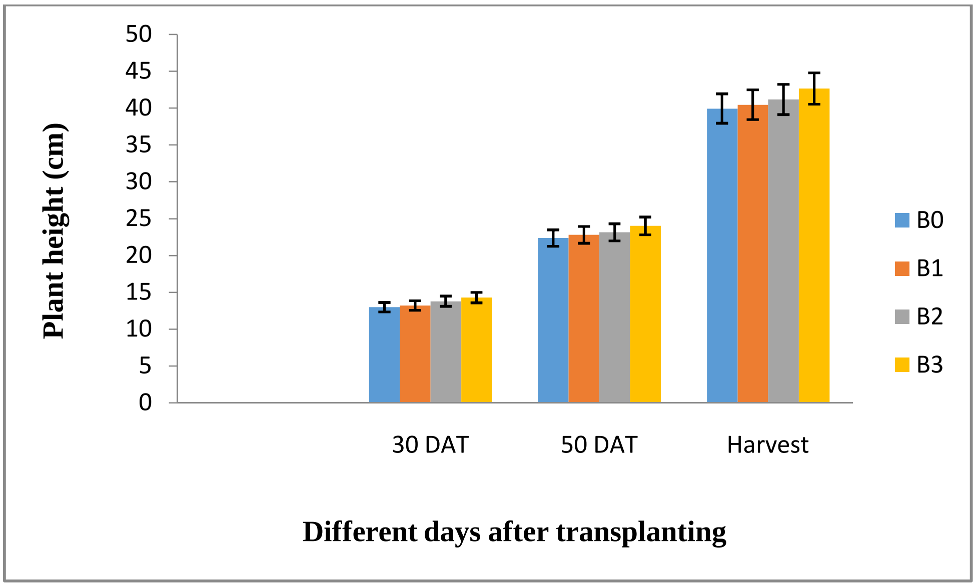

Fig. 3. Effect of boron on plant height of cauliflower

B_0: Control, B_1:1 kg boron ha^{-1}, B_2: 1.5 kg boron ha^{-1}, B_3: 2 kg boron ha^{-1}

Table 1. Combined effect of zinc and boron on plant height of cauliflower

Treatments	Plant height at 30 DAS (cm)	Plant height at 50 DAS (cm)	Plant height at harvest (cm)
Zn_0B_0	11.50 g	20.17 i	36.47 j
Zn_0B1	11.67 g	20.93 hi	36.80 i
Zn_0B_2	12.03 fg	21.13 hi	37.30 hi
Zn_0B_3	12.10 fg	21.20 h	37.57 h
Zn_1B_0	12.27 fg	21.53 gh	38.17 g
Zn_1B_1	12.50 f	22.17 fg	38.66 fg
Zn_1B_2	12.93 ef	22.43 fg	39.00 fg
Zn_1B_3	13.17 e	22.70 f	39.77 f
Zn_2B_0	13.56 de	23.03 ef	40.24 e
Zn_2B_1	13.97 c-e	23.23 de	40.83 de
Zn_2B_2	14.22 c-e	23.52 c-e	41.53 d
Zn_2B_3	14.61 cd	23.97 b-d	41.90 cd
Zn_3B_0	15.24 cd	24.30 bc	42.37 c
Zn_3B_1	15.61 c	24.77 bc	42.93 bc
Zn_3B_2	15.98 b	25.20 ab	43.68 ab
Zn_3B_3	16.82 a	26.02 a	44.50 a
$LSD_{(0.05)}$	0.692	0.757	1.223
CV (%)	1.37	2.28	4.87

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

Zn_0: Control, Zn_1:1.5 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}, Zn_3: 2.5 kg zinc ha^{-1}

B_0: Control, B_1:1 kg boron ha^{-1}, B_2: 1.5 kg boron ha^{-1}, B_3: 2 kg boron ha^{-1}

On the other hand, at 30, 50 and harvest DAT the lowest plant height (11.50 cm, 20.17 cm and 36.47 cm) was recorded from the control (Zn_0B_0) treatment (Table 1). Mehrotra and Mishra (1994) reported that zinc was applied to cauliflower cultivars and plant height was increased.

4.2 Number of leaves plant^{-1}

Application of zinc with different concentration significantly increases the number of leaves per plant (Appendix III). At 30 DAT and harvest the maximum number of leaves per plant (6.50 and 19.23) was produced by treatment Zn_3 (Fig. 4). On the other hand, the minimum number of leaves per plant (4.05 and 17.24) was obtained from control (Zn_0) treatment. Duraishami and Sakal (2005) also found similar results.

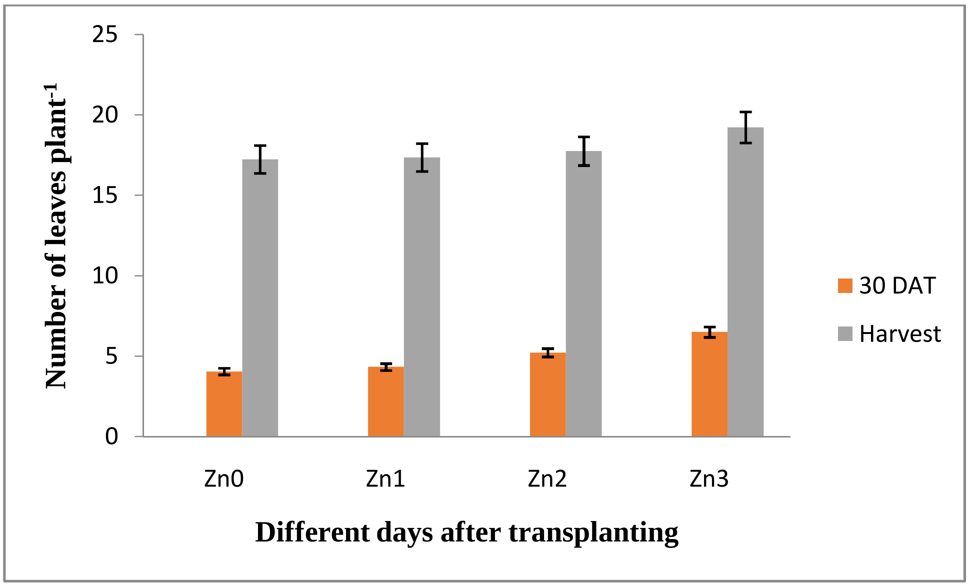

Fig. 4. Effect of zinc on number of leaves plant^{-1} of cauliflower

Zn_0: Control, Zn_1:1.5 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}, Zn_3: 2.5 kg zinc ha^{-1}

There was significant variation found in case of production of leaves per plant at 30 DAT and harvest due to the effect of boron with different concentrations (Appendix III). Boron at 2 kg ha^{-1} (B_3) treatment produced the maximum number of leaves per plant (6.33 and 19.35) which was identical with that of the control treatment (B_0) (Fig. 5). This result support to that of Waring and Theiler (2003).

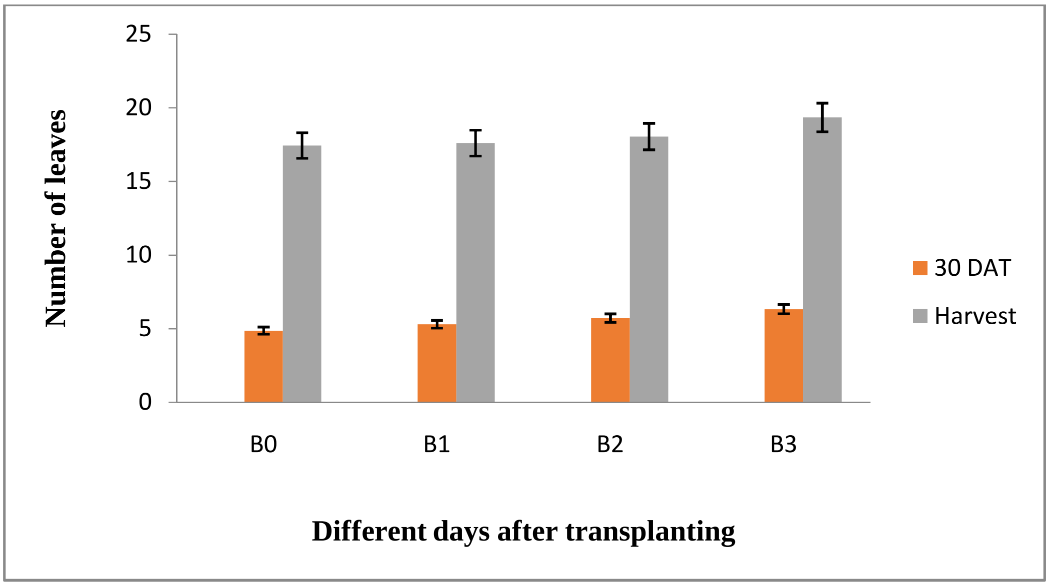

Fig. 5. Effect of boron on number of leaves plant^{-1} of cauliflower

B_0: Control, B_1:1 kg boron ha^{-1}, B_2: 1.5 kg boron ha^{-1}, B_3: 2 kg boron ha^{-1}

They stated that number of leaves per plant increased with zinc levels.

The number of leaves per plant was significantly influenced by the interaction effect of zinc and boron with different levels (Appendix III). At 30 DAS and harvest the maximum number of leaves per plant ((8.53 and 22.03) was recorded from the treatment combination of Zn_3B_3 and the minimum number of leaves (3.33 and 15.71) was found from (control) Zn_0B_0 treatment (Table 2).

4.3 Leaf length

A significant variation was observed in leaf length due to the application of zinc (Appendix IV). The maximum leaf length (20.14 cm) was recorded from the Zn_3 treatment (2.5 kg zinc ha^{-1}) while the minimum leaf length (15.66 cm) was found in Zn_0 treatment (Table 3). Andrejiova *et al.* (2011) studied in a field trial and found that application of zinc provided better results in case of leaf length. Its deficiency retards growth and development of cauliflower leaves.

Table 2.Combined effect of zinc and boron on number of leaves plant^{-1} of cauliflower

Treatments	Number of leaves per plant at 30 DAS	Number of leaves per plant at harvest
Zn_0B_0	3.33 ij	15.71 h
Zn_0B1	3.67 i	16.00 gh
Zn_0B_2	4.00 hi	16.40 g
Zn_0B_3	4.31 hi	16.87 fg
Zn_1B_0	4.63 g-i	17.12 f
Zn_1B_1	4.97 gh	17.63 e-g
Zn_1B_2	5.22 g	18.02 ef
Zn_1B_3	5.67 fg	18.40 e
Zn_2B_0	6.00 d-f	18.78 de
Zn_2B_1	6.41 de	19.17 d
Zn_2B_2	6.72 d	19.55 cd
Zn_2B_3	6.91 cd	19.96 cd
Zn_3B_0	7.35 bc	20.23 c
Zn_3B_1	7.68 bc	20.73 bc
Zn_3B_2	7.92 ab	21.24 ab
Zn_3B_3	8.53 a	22.03 a
$LSD_{(0.05)}$	1.163	0.882
CV (%)	6.27	5.63

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

Zn_0: Control, Zn_1:1.5 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}, Zn_3: 2.5 kg zinc ha^{-1}

B_0: Control, B_1:1 kg boron ha^{-1}, B_2: 1.5 kg boron ha^{-1}, B_3: 2 kg boron ha^{-1}

Leaf length was significantly differs by boron application (Appendix IV). The maximum length (18.40cm) and the minimum length (17.17cm) was found from the B_3 (2 kg boron ha^{-1}) and B_0 (control) treatment, respectively (Table 4). This result support to that of Kumar and Malabasari (2012).

The interaction effect between zinc and boron on leaf length was also significant (Appendix IV). The highest value of leaf length was (21.17cm) recorded from Zn_3B_3 (zinc 2.5 kg ha^{-1} and boron 2 kg ha^{-1}) treatment and the lowest value (15.13cm) was obtained from control treatment Zn_0B_0 (Table 5).

4.4 Leaf breadth

A significant variation was observed in leaf breadth due to the application of zinc (Appendix IV). The maximum leaf breadth (11.81 cm) was recorded from the Zn_3 (2.5 kg zinc ha^{-1}) treatment while the minimum leaf breadth (6.83 cm) was found in (control) Zn_0 treatment (Table 4).

Leaf breadth was significantly differs by boron application (Appendix IV). However, the maximum breadth (9.68cm) and the minimum breadth (8.16 cm) was found from B_3 treatment (2 kg boron ha^{-1}) and control (B_0) treatment, respectively (Table 4). Pardeep *et al.* (2006) conducted a field trial and found the similar results.

The interaction effect between zinc and boron on leaf breadth was also significant (Appendix IV). The highest value of leaf breadth (12.71 cm) was recorded from Zn_3B_3 treatment and the lowest value (6.23 cm) was obtained from treatment Zn_0B_0 (control) (Table 5). Singh *et al.* (2003) found that their combined effect provided substantial results in leaf breadth.

4.5 Leaf area

Application of zinc with different concentration significantly increases the leaf area (Appendix IV). The maximum (203.75 cm^2) leaf area was produced by Zn_3 (2.5 kg zinc ha^{-1}) treatment followed by (160.41 cm^2) Zn_2 treatment and the minimum area (107.06 cm^2) was obtained from control (Zn_0) treatment (Table 3).

Table 3. Effect of zinc on leaf length, leaf breadth, leaf area of cauliflower

Treatments	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)
Zn_0	15.66 c	6.83 c	107.06 c
Zn_1	16.44 c	7.57 c	118.23 c
Zn_2	18.43 b	9.26 b	160.41 b
Zn_3	20.14 a	11.81 a	203.75 a
$LSD_{(0.05)}$	0.784	0.430	11.17
CV %	3.98	4.72	6.48

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

Zn_0: Control, Zn_1:1.5 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}, Zn_3: 2.5 kg zinc ha^{-1}

Table 4. Effect of boron on leaf length, leaf breadth, leaf area of cauliflower

Treatments	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)
B_0	17.17 c	8.16 c	121.85 c
B_1	17.55 bc	8.74 b	135.96 c
B_2	17.98 ab	9.17 b	161.13 b
B_3	18.40 a	9.68 a	182.51 a
$LSD_{(0.05)}$	0.380	0.430	14.11
CV %	5.84	4.72	5.02

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

B_0: Control, B_1:1 kg boron ha^{-1}, B_2: 1.5 kg boron ha^{-1}, B_3: 2 kg boron ha^{-1}

There some significant variation was found in case of leaf area due to the effect of boron with different concentrations (Appendix IV). Boron at B_3 treatment produced the maximum (182.51 cm^2) leaf area which was identical with that of the control (B_0) treatment gave the minimum leaf area (121.85 cm^2) (Table 4). Baylan *et al.* (1995) supported the results.

Leaf area was also significantly influenced by the interaction effect of Zn and B (Appendix IV). The maximum (275.57 cm^2) leaf area was recorded from the treatment combination of Zn_3B_3 treatment (zinc 2.5 kg ha^{-1} and boron 2 kg ha^{-1}) and the minimum (94.37 cm^2) leaf area was found from Zn_0B_0 (control) treatment (Table 5).

4.6 Days from transplanting to curd initiation

Significant difference was noted on days required from transplanting to curd initiation by different levels of zinc (Appendix IV). The maximum days (47.17) were required in Zn_0 treatment and the minimum days were required (43.83) in Zn_3 (2.5 kg zinc ha^{-1}) treatment (Table 6). Duraisami and Sakal (2005) stated that transplanting to curd initiation decreased with increasing zinc level.

Significant variation was found in case of days from transplanting to curd initiation due to application of different levels of boron (Appendix IV). The maximum days (46.82) were required in B_0 (control) treatment which was followed by B_2 treatment and the minimum days were required (43.65) in B_3 (2 kg boron ha^{-1}) treatment (Table 7).

The interaction effect was observed in combination of zinc and boron application. There was significant effect on days required for transplanting to curd initiation (Appendix IV). The lowest value (43.33) was recorded in Zn_3B_3 treatment combination and the highest value was (47.75) in Zn_0B_0 (control) treatment (Table 8).

4.7 Days from transplanting to 50% curd initiation

A significant variation was found from zinc application in days from transplanting to 50% curd initiation (Appendix IV). The maximum number of days (50.17) were required from control treatment (Zn_0) and the minimum number of days (47.42) was recorded from Zn_3 (2.5 kg zinc ha^{-1}) treatment (Table 6).

Table 5. Combined effect of zinc and boron on leaf length, leaf breadth, leaf area of cauliflower

Treatments	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)
Zn_0B_0	15.13 j	6.23 j	94.37 i
Zn_0B1	15.60 ij	6.77 j	105.69 hi
Zn_0B_2	15.87 i	7.03 ij	111.85 gh
Zn_0B_3	16.03 hi	7.27 h-j	116.31 f-h
Zn_1B_0	16.53 gh	7.53 hi	121.65 fg
Zn_1B_1	16.63 g	8.01 g-i	130.31 e-g
Zn_1B_2	17.07 fg	8.22 g	136.53 f
Zn_1B_3	17.40 e-g	8.72 fg	140.13 ef
Zn_2B_0	17.73 ef	9.23 f	154.26 e
Zn_2B_1	18.33 e	9.61 e	168.70 de
Zn_2B_2	18.57 de	9.97 de	175.26 d
Zn_2B_3	19.00 cd	10.23 cd	183.43 c
Zn_3B_0	19.36 c	10.85 c	197.13 bc
Zn_3B_1	19.63 bc	11.34 bc	212.14 b
Zn_3B_2	20.23 b	11.94 b	239.21 ab
Zn_3B_3	21.17 a	12.71 a	275.57 a
$LSD_{(0.05)}$	0.257	0.542	6.16
CV (%)	4.72	4.48	2.18

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

Zn_0: Control, Zn_1:1.5 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}, Zn_3: 2.5 kg zinc ha^{-1}

B_0: Control, B_1:1 kg boron ha^{-1}, B_2: 1.5 kg boron ha^{-1}, B_3: 2 kg boron ha^{-1}

A significant variation was also found in days from transplanting to 50% curd initiation due to boron application (Appendix IV). The maximum days (49.44) were required in B_0 (control) treatment and the minimum days (47.23) required in B_3 treatment (Table 7).

The combined effect of zinc and boron was significant on days from transplanting to 50% curd initiation (Appendix IV). The maximum number of days (50.33) required for 50% curd initiation from Zn_0B_0 treatment combination and the minimum number of days (46.57) from Zn_3B_3 treatment combination (Table 8).

4.8 Days from curd initiation to harvest

A significant effect was recorded on days from curd initiation to harvest due to application of zinc (Appendix V). The maximum (12.03) days from curd initiation to harvest was found from control (Zn_0) treatment and the minimum (10.21) days from curd initiation to harvest was found from Zn_3 treatment (Table 6). Balyan *et al.* (2004) conducted an experiment and agreed with the results.

The effect of boron application on days from curd initiation to harvest was significant (Appendix V). The highest (11.81) value of days required for curd initiation to harvest in B_0 treatment and the lowest value (9.79) was recorded from B_3 treatment (Table 7). The result was similar to those of Mukhopadhayay and Jana (2002).

The interaction effect between zinc and boron was also found significant (Appendix V). The combined effect of zinc and boron was affects the days from curd initiation to harvest. The maximum days (12.53) was recorded from the treatment combination of Zn_0B_0 treatment**.** The lowest (10.03) was observed from the Zn_3B_3 treatment combination (Table 8).

Table 6. Effect of zinc on days from transplanting to curd initiation, transplanting to 50% curd initiation, curd initiation to harvest of cauliflower

Treatments	Transplanting to curd initiation (days)	Transplanting to 50% curd initiation (days)	Curd initiation to harvest (days)
Zn_0	47.17 d	50.17 d	12.03 c
Zn_1	44.45 c	49.53 c	11.23 c
Zn_2	44.40 b	48.81 b	10.77 b
Zn_3	43.83 a	47.42 a	10.21 a
$LSD_{(0.05)}$	0.572	0.640	0.560
CV %	1.12	1.07	0.48

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

Zn_0: Control, Zn_1:1.5 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}, Zn_3: 2.5 kg zinc ha^{-1}

Table 7. Effect of boron on days from transplanting to curd initiation, transplanting to 50% curd initiation, curd initiation to harvest of cauliflower

Treatments	Transplanting to curd initiation (days)	Transplanting to 50% curd initiation (days)	Curd initiation to harvest (days)
B_0	46.82 d	49.44 d	11.81 c
B_1	45.08 c	49.03 c	10.67 c
B_2	44.26 b	48.53 b	10.14 b
B_3	43.65 a	47.23 a	9.79 a
$LSD_{(0.05)}$	0.740	0.410	0.350
CV %	3.85	1.36	1.15

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

B_0: Control, B_1:1 kg boron ha^{-1}, B_2: 1.5 kg boron ha^{-1}, B_3: 2 kg boron ha^{-1}

Table 8. Combined effect of zinc and boron on days from transplanting to curd initiation, transplanting to 50% curd initiation, curd initiation to harvest of cauliflower

Treatments	Transplanting to curd initiation (days)	Transplanting to 50% curd initiation (days)	Curd initiation to harvest (days)
Zn_0B_0	47.75 j	50.33 i	12.53 i
Zn_0B1	47.23 i	50.27 h	11.90 h
Zn_0B_2	46.82 hi	50.02 g	11.53 gh
Zn_0B_3	46.50 gh	49.68 fg	11.68 fg
Zn_1B_0	46.21 g	49.46 fg	11. 53 f
Zn_1B_1	45.92 fg	49.21 f	11.43 ef
Zn_1B_2	45.68 fg	48.94 ef	11.27 e
Zn_1B_3	45.32 f	48.70 e	11.17 de
Zn_2B_0	45.03 ef	48.49 de	11.03 d
Zn_2B_1	44.80 d-f	48.27 de	10.92 cd
Zn_2B_2	44.55 de	48.01 d	10.72 c
Zn_2B_3	44.20 d	47.73 cd	10.57 bc
Zn_3B_0	43.98 cd	47.53 c	10.43 bc
Zn_3B_1	43.73 bc	47.25 bc	10.23 b
Zn_3B_2	43.52 b	47.08 b	10.13 ab
Zn_3B_3	43.33 a	46.57 a	10.03 a
$LSD_{(0.05)}$	0.201	0.060	0.100
CV (%)	8.49	10.27	3.48

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

Zn_0: Control, Zn_1: 1.5 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}, Zn_3: 2.5 kg zinc ha^{-1}

B_0: Control, B_1: 1 kg boron ha^{-1}, B_2: 1.5 kg boron ha^{-1}, B_3: 2 kg boron ha^{-1}

4.9 Length of the biggest leaf at harvest

The length of the biggest leaf was varied significantly due to the application of different levels of zinc (Appendix V). The treatment Zn_3 gave the highest leaf length (42.15 cm) and the control treatment (Zn_0) gave the lowest leaf length (40.26 cm) at harvest (Table 9). Phor *et al.* (1995) found that leaf length increased due to the application of zinc but excessive application resulted in decreasing production.

A significant variation was observed in case of boron application with different concentration (Appendix V). The highest length of leaf (41.51 cm) was found from B_3 treatment (2 kg boron ha^{-1}) while the lowest control (B_0) treatment gave the lowest (40.97 cm) length at harvest (Table 10).

In case of combined effect of zinc and boron application significant variation was observed (Appendix V). However, the maximum length of leaf (42.39 cm) was found from treatment combination Zn_3B_3 which was statistically similar with Zn_3B_2 (42.25) treatment and the minimum length (40.09 cm) was found from the treatment combination of Zn_0B_0 at harvest (Table 11).

4.10 Breadth of the biggest leaf at harvest

Application of zinc at different levels significantly increased the breadth of leaf (Appendix V). The maximum (12.97 cm) breadth of leaf was found from (Zn_3) treatment and the minimum (11.19 cm) breadth of leaf was observed in control (Zn_0) treatment at harvest (Table 9).

Due to different levels of boron application significant difference was found on this parameter (Appendix V). The maximum (12.28 cm) breadth was found in B_3 treatment and the minimum (11.73 cm) breadth was recorded from control (B_0) treatment (Table 10). The result was similar to those of Pandey and Sinha (1999).

The interaction effect of zinc and boron had significant effect on breadth of leaf. The maximum (13.35 cm) breadth of leaf was observed in Zn_3B_3 and the minimum (11.02 cm) breadth was recorded from control treatment Zn_0B_0 (Table 11).

Table 9. Effect of zinc on length of biggest leaf, breadth of biggest leaf and curd diameter at harvest of cauliflower

Treatments	Length of biggest leaf at harvest (cm)	Breadth of biggest leaf at harvest (cm)	Curd diameter at harvest (cm)
Zn_0	40.26 c	11.19 c	13.60 c
Zn_1	40.85 c	11.64 c	13.65 c
Zn_2	41.48 b	12.21 b	13.92 b
Zn_3	42.15 a	12.97 a	14.53 a
$LSD_{(0.05)}$	0.590	0.450	0.050
CV %	0.56	1.24	0.59

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

Zn_0: Control, Zn_1: 1.5 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}, Zn_3: 2.5 kg zinc ha^{-1}

4.11 Curd diameter at harvest

A significant variation was found due to the application of zinc at different levels on the curd diameter at harvest (Appendix V). The maximum (14.53 cm) curd diameter was recorded from treatment Zn_3 and the minimum (13.60 cm) curd diameter was found from the control (Zn_0) treatment (Table 9). This result support to that of Nayak and Nandi (2000).

In case of boron application significant variation was also found on curd diameter at harvest (Appendix V). The maximum (13.67 cm) curd diameter was found from treatment B_3 (2 kg boron ha^{-1}) and the minimum (12.55 cm) curd diameter was found from the control (B_0) treatment (Table 10).

The interaction effect between zinc and boron at different levels was also found significantly on curd diameter. The maximum (16.7 cm) diameter had recorded from the treatment combination of Zn_3B_3 which was statistically similar with Zn_3B_2 (16.44) treatment and the minimum (13.03 cm) curd diameter was observed in control treatment Zn_0B_0 (Table 11). Alam and Jahan (2007) agreed with the results.

Table 10. Effect of boron on length of biggest leaf, breadth of biggest leaf and curd diameter at harvest of cauliflower

Treatments	Length of biggest leaf at harvest (cm)	Breadth of biggest leaf at harvest (cm)	Curd diameter at harvest (cm)
B_0	40.97 c	11.73 c	12.55 c
B_1	41.17 c	11.88 bc	12.68 c
B_2	41.32 b	12.01 ab	12.92 b
B_3	41.51 a	12.28 a	13.67 a
$LSD_{(0.05)}$	0.200	0.150	0.130
CV %	1.92	0.82	2.65

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

B_0: Control, B_1:1 kg boron ha^{-1}, B_2: 1.5 kg boron ha^{-1}, B_3: 2 kg boron ha^{-1}

4.12 Pure Curd weight

The curd weight varied significantly due to different levels of zinc application (Appendix V). The maximum (705.37 g) curd weight was recorded from Zn_3 treatment (2.5 kg zinc ha^{-1}) and the minimum (443.50 g) from the control treatment (Zn_0) (Table 12). Bijarnia (2007) showed that increasing zinc fertilizer rate enhanced curd weight and yield.

The curd weight also differ significantly in case of boron application at different levels (Appendix V). The highest (698.20 g) curd weight per plant was obtained from B_3 treatment and the lowest (418.60 g) was recorded from (B_0) control treatment (Table 13). Swain *et al.* (2015) conducted an experiment and found that application of micronutrients (boron fertilizers) controls all the physiological activities which helps the maximum fruit yield.

A significant interaction effect was found for zinc and boron on the curd weight. The maximum curd weight (765.30 g) was recorded from treatment combination of Zn_3B_3 and the minimum (394.50 g) from treatment combination of Zn_0B_0 (Table 14).

Table 11. Combined effect of boron and zinc on length of biggest leaf, breadth of biggest leaf and curd diameter at harvest of cauliflower

Treatments	Length of biggest leaf at harvest (cm)	Breadth of biggest leaf at harvest (cm)	Curd diameter at harvest (cm)
Zn_0B_0	40.09 i	11.02 j	13.03 hi
Zn_0B1	40.17 hi	11.13 i	13.30 h
Zn_0B_2	40.33 h	11.24 hi	13.73 gh
Zn_0B_3	40.47 gh	11.37 g-i	14.27 gh
Zn_1B_0	40.63 g	11.49 gh	14.49 g
Zn_1B_1	40.74 g	11.60 g	14.67 fg
Zn_1B_2	40.93 fg	11.72 fg	14.90 ef
Zn_1B_3	41.07 f	11.85 e-g	15.07 e
Zn_2B_0	41.23 ef	11.97 ef	15.23 de
Zn_2B_1	41.37 e	12.13 d-f	15.48 d
Zn_2B_2	41.57 cd	12.25 d	15.65 cd
Zn_2B_3	41.73 c	12.37 cd	15.88 c
Zn_3B_0	41.91 b	12.48 b-d	16.03 bc
Zn_3B_1	42.07 b	12.70 bc	16.27 b
Zn_3B_2	42.25 a	12.87 b	16.44 ab
Zn_3B_3	42.39 a	13.35 a	16.79 a
$LSD_{(0.05)}$	0.160	0.011	0.256
CV (%)	10.56	2.24	5.67

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

Zn_0: Control, Zn_1: 1.5 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}, Zn_3: 2.5 kg zinc ha^{-1}

B_0: Control, B_1: 1 kg boron ha^{-1}, B_2: 1.5 kg boron ha^{-1}, B_3: 2 kg boron ha^{-1}

Table 12. Effect of zinc on pure curd weight and curd weight with leaf at harvest of cauliflower

Treatments	Pure curd weight (g)	Curd weight with leaf at harvest (kg)
Zn_0	443.50 c	0.68 d
Zn_1	498.80 c	1.02 c
Zn_2	597.20 b	1.29 b
Zn_3	705.37 a	1.55 a
$LSD_{(0.05)}$	0.567	0.260
CV %	7.97	2.71

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

Zn_0: Control, Zn_1:1.5 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}, Zn_3: 2.5 kg zinc ha^{-1}

Table 13. Effect of boron on pure curd weight and curd weight with leaf at harvest of cauliflower

Treatments	Pure curd weight (g)	Curd weight with leaf at harvest (kg)
B_0	418.60 c	1.07 d
B_1	477.40 c	1.14 c
B_2	583.30 b	1.31 b
B_3	698.20 a	1.56 a
$LSD_{(0.05)}$	0.018	0.070
CV %	6.38	2.84

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

B_0: Control, B_1:1 kg boron ha^{-1}, B_2: 1.5 kg boron ha^{-1}, B_3: 2 kg boron ha^{-1}

4.13 Curd weight with leaf at harvest

Curd weight with leaf at harvest was also found to differ significantly due to application of zinc at different concentrations (Appendix VI). The maximum curd weight (1.55 kg) with leaf was recorded from the treatment Zn_3 (2.5 kg zinc ha^{-1})

and the minimum (0.68 kg) was from the control (Zn_0) treatment at final harvest of the crop (Table 12). Chhipa (2005) conducted an experiment and supported results.

A significant variation was observed on curd weight with leaf due to the application of different concentration of boron (Appendix VI). The treatment B_3 gave the maximum (1.56 kg) curd weight. On the other hand control treatment (B_0) showed the minimum (1.07 kg) curd weight with leaf at harvest (Table 13).

The interaction effect between Zn and B show significant variation on curd weight with leaf (Appendix VI). The highest value (1.59 kg) was recorded from treatment combination Zn_3B_3. The lowest value (0.58 kg) was found from the treatment combination of Zn_0B_0 (Table 14). Kuldeep *et al*. (2011) said that, it is confirmed from the results that combination of zinc and boron as soil application has the ability to increase the growth and yield of cauliflower.

4.14 Curd yield plot^{-1}

A significant variation was found due to the application of zinc at different levels on the curd yield per plot (Appendix VI). The maximum (1.52 kg) curd yield per plot was recorded from Zn_3 (zinc 2.5 kg ha^{-1}) treatment and the minimum (0.93 kg) was found from the control (Zn_0) treatment (Table 15). Iyengal and Kibe (1998) investigated the effects of zinc levels on curd yield and quality of cauliflower.

The curd yield per plot as also varied significantly by the application of boron at different levels (Appendix VI). The maximum (1.53 kg) curd yield per plot was obtained from B_3 (2 kg boron ha^{-1}) and the minimum (1.05 kg) was recorded from the control (B_0) treatment (Table 16). Lewis (2000) supported the results.

A significant interaction effect was found due to zinc and boron on curd yield per plot (Appendix VI). The highest value (1.65 kg) was found from treatment combination Zn_3B_3 and the lowest (0.9 kg) from the treatment combination of Zn_0B_0 (Table 17). Shalaby *et al.* (2014) investigated the response of cauliflower cultivars varying in growth habit to rates of zinc, boron and resulted in significantly higher total curd yield of cauliflower.

Table 14. Combined effect of zinc and boron on pure curd weight and curd weight with leaf at harvest of cauliflower

Treatments	Pure curd weight (g)	Curd weight with leaf at harvest (kg)
Zn_0B_0	394.50 h	0.58 j
Zn_0B1	413 gh	0.62 ij
Zn_0B_2	426.40 g	0.71 hi
Zn_0B_3	442.80 fg	0.81 h
Zn_1B_0	463.60 fg	0.95 g
Zn_1B_1	486.20 f	1.05 fg
Zn_1B_2	503.40 ef	1.16 f
Zn_1B_3	536.20 e	1.22 ef
Zn_2B_0	559.80 de	1.31 e
Zn_2B_1	582.70 de	1.38 de
Zn_2B_2	611.30 d	1.41 cd
Zn_2B_3	638.10 cd	1.44 b-d
Zn_3B_0	655.40 c	1.49 b-d
Zn_3B_1	682.60 bc	1.51 a-c
Zn_3B_2	720.40 b	1.53 ab
Zn_3B_3	765.30 a	1.59 a
$LSD_{(0.05)}$	18.456	0.114
CV (%)	6.34	6.05

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

Zn_0: Control, Zn_1: 1.5 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}, Zn_3: 2.5 kg zinc ha^{-1}

B_0: Control, B_1: 1 kg boron ha^{-1}, B_2: 1.5 kg boron ha^{-1}, B_3: 2 kg boron ha^{-1}

Table 15. Effect of zinc on curd yield plot^{-1}, curd yield ha^{-1}at harvest of cauliflower

Treatments	Curd yield plot^{-1} (kg)	Curd yield ha^{-1} (ton)
Zn_0	0.93 d	9.28 d
Zn_1	0.98 c	9.80 c
Zn_2	1.19 b	11.90 b
Zn_3	1.52 a	15.20 a
$LSD_{(0.05)}$	0.050	0.180
CV %	4.20	5.75

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

Zn_0: Control, Zn_1: 1.5 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}, Zn_3: 2.5 kg zinc ha^{-1}

Table 16. Effect of boron on curd yield plot^{-1}, curd yield ha^{-1}at harvest of cauliflower

Treatments	Curd yield plot^{-1} (kg)	Curd yield ha^{-1} (ton)
B_0	1.05 d	10.49 d
B_1	1.16 c	11.16 c
B_2	1.32 b	13.20 b
B_3	1.53 a	15.30 a
$LSD_{(0.05)}$	0.110	0.640
CV %	3.20	7.38

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

B_0: Control, B_1:1 kg boron ha^{-1}, B_2: 1.5 kg boron ha^{-1}, B_3: 2 kg boron ha^{-1}

4.15 Curd yield ha^{-1}

A significant variation on curd yield per hectare was found due to the application of zinc at different levels (Appendix VI). The maximum (15.20 ton ha^{-1}) curd yield was recorded from Zn_3 (zinc 2.5 kg ha^{-1}) treatment and the minimum (9.28 ton) from the control (Zn_0) treatment (Table 15). Zubair *et al.* (2011) found the maximum curd yield when plots received zinc fertilizers. Shumiati (2003) conducted an experiment in Peshawar, Pakistan in the summer to determine the appropriate zinc fertilizer for highest curd yield and its effect on various agronomic characters of cauliflower and supported the results.

The effect of boron at different levels on the curd yield was also significant (Appendix VI). The maximum curd yield (15.30 ton ha^{-1}) was recorded from B_3 treatment and the minimum (10.49 ton ha^{-1}) from the control (B_0) treatment (Table 16). This result support to those of Raghubanshi *et al*. (2013). Shukla *et al*. (2003) found that individual application of nutrient provide better results as compared to control.

The interaction effect due to zinc and boron at different levels were also show the significant effect. However, the highest value was (16.50 ton ha^{-1}) recorded from treatment combination of Zn_3B_3 and the lowest (9.0 ton ha^{-1}) from the Zn_0B_0 treatment combination (Table 17). Singh *et al.* (1992) found that total yield was increased as compared to control when plots received zinc and boron combindly.

4.16 Economics analysis

The variation in cost of production was noticed due to different levels of zinc and boron (Table 18). The production cost of the highest (Tk.117400 ha^{-1}) when Zn_3B_3 (2.5 kg zinc ha^{-1} and 2 kg boron ha^{-1}) and the lowest cost of production (Tk. 57400 ha^{-1}) was found in Zn_0B_0 treatment. The highest gross return (Tk. 257680 ha^{-1}) was obtained from treatment Zn_3B_3 (2.5 kg zinc ha^{-1} and 2 kg boron ha^{-1}) while the lowest (Tk. 60500 ha^{-1}) was found from treatment combination Zn_0B_0. It was evident that the maximum net return (Tk. 129280 ha^{-1}) was obtained from Zn_3B_3 (2.5 kg zinc ha^{-1} and 2 kg boron ha^{-1}) treatment and the plants which were in control treatment gave the minimum net return (Tk. 3100 ha^{-1}). The maximum (2.55) benefit cost ratio (BCR) was recorded in Zn_3B_3 (2.5 kg zinc ha^{-1} and 2 kg boron ha^{-1}) treatment while the minimum (1.05) was found against control treatment.

Table 17. Combined effect of zinc and boron on curd yield plot^{-1} and curd yield ha^{-1} of cauliflower

Treatments	Curd yield (kg plot^{-1})	Curd yield (ton ha^{-1})
Zn_0B_0	0.90 i	9.0 i
Zn_0B_1	0.91 hi	9.10 hi
Zn_0B_2	0.93 g-i	9.30 g-i
Zn_0B_3	0.95 g-i	9.50 g-i
Zn_1B_0	0.97 gh	9.70 gh
Zn_1B_1	0.99 gh	9.90 gh
Zn_1B_2	1.04 fg	10.40 fg
Zn_1B_3	1.09 fg	10.90 fg
Zn_2B_0	1.16 e-g	11.60 e-g
Zn_2B_1	1.20 ef	12 ef
Zn_2B_2	1.26 e	12.60 e
Zn_2B_3	1.31 de	13.10 de
Zn_3B_0	1.37 d	13.70 d
Zn_3B_1	1.44 c	14.40 c
Zn_3B_2	1.52 b	15.20 b
Zn_3B_3	1.65 a	16.50 a
$LSD_{(0.05)}$	0.122	0.609
CV (%)	3.77	8.24

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

Zn_0: Control, Zn_1: 1.5 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}, Zn_3: 2.5 kg zinc ha^{-1}

B_0: Control, B_1: 1 kg boron ha^{-1}, B_2: 1.5 kg boron ha^{-1}, B_3: 2 kg boron ha^{-1}

Table 18. Cost and return analysis of cauliflower due to the application of zinc and boron

Treatments	Curd yield (ton ha^{-1})	Gross return (tk ha^{-1})	Total cost of production (tk ha^{-1})	Net return (tk ha^{-1})	Benefit cost ratio (BCR)
Zn_0B_0	9.0	60500	57400	3100	1.05
Zn_0B_1	9.1	67700	62400	5300	1.08
Zn_0B_2	9.3	75200	64058	11142	1.15
Zn_0B_3	9.5	87050	67650	19400	1.25
Zn_1B_0	9.7	95780	69240	26540	1.34
Zn_1B_1	9.9	102450	72917	30533	1.38
Zn_1B_2	10.4	107530	77300	37070	1.43
Zn_1B_3	10.9	127870	83700	44100	1.53
Zn_2B_0	11.6	137000	86850	51150	1.65
Zn_2B_1	12.0	149600	90600	69000	1.76
Zn_2B_2	12.6	167050	99760	77290	1.89
Zn_2B_3	13.1	190000	100540	86460	1.97
Zn_3B_0	13.7	205470	103170	95300	2.08
Zn_3B_1	14.4	221550	109160	100390	2.19
Zn_3B_2	15.2	235780	112500	118280	2.28
Zn_3B_3	16.5	257680	117400	129280	2.55

Net return = Gross return **-** Total cost of production

Gross return = Curd yield x Market price

Benefit cost ratio = Gross return / Total cost of product

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted at the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from October 2016 to February 2017 to find out the effect of zinc and boron on growth and yield of cauliflower. The experiment consists of four different concentrations of zinc viz. Zn_0: Control, Zn_1: 1.5 kg Zn ha^{-1}, Zn_2: 2 kg Zn ha^{-1}, Zn_3: 2.5 kg Zn ha^{-1}) and four levels of boron, viz. B_0: Control, B_1: 1 kg B ha^{-1}, B_2: 1.5 kg B ha^{-1}, B_3: 2 kg B ha^{-1}). There were 16 treatment combinations. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data on different growth, yield contributing characters and yield were recorded to find out best combination of boron and zinc for higher yield of cauliflower.

In case of zinc application, the highest plant height at 30 DAS (14.70 cm), 50 DAS (25.03 cm) and at harvest (42.13 cm), the maximum number of leaves per plant at 30 DAS (6.50) and at harvest (19.23), the maximum leaf length (20.14 cm), the maximum leaf breadth (11.81 cm), the maximum leaf area (203.75 cm^2), the maximum transplanting to curd initiation (43.83 days), the maximum days required for 50% curd initiation (47.42 days), the maximum curd initiation to harvest (10.21 days), the maximum length of biggest leaf at harvest (42.15 cm), the maximum breadth of biggest leaf at harvest (12.97 cm), the maximum curd diameter (14.51 cm), the maximum pure curd weight (705.37 kg), the maximum curd weight with leaves (1.55 kg), maximum curd yield per plot (1.52 kg), the maximum curd yield per ha (15.24 ton) were recorded from the 2.5 kg zinc ha^{-1} that is Zn_3 treatment.

On the other hand, the shortest plant height at 30 DAS (11.20 cm), 50 DAS (20.86 cm) and at harvest (37.03 cm), the shortest number of leaves per plant at 30 DAS (4.05) and at harvest (17.24), the shortest leaf length (15.66 cm), the shortest leaf breadth (6.83 cm), the shortest leaf area (107.06 cm^2), the shortest transplanting to curd initiation (47.17 days), the shortest days required for 50% curd initiation (50.17 days), the shortest curd initiation to harvest (12.03), the shortest length of biggest leaf at harvest (40.26 cm), the shortest breadth of biggest leaf at harvest (11.19 cm), the shortest curd diameter (13.60 cm), the shortest pure curd weight (443.52 kg), the shortest curd weight with leaves (0.68 kg), shortest curd yield per plot (0.93 kg), the shortest curd yield per ha (9.28 ton) were recorded from the control treatment that is Zn_0 treatment.

In case of boron application the highest plant height at 30 DAS (14.28 cm), 50 DAS (23.51 cm) and at harvest (41.66 cm), the maximum number of leaves per plant at 30 DAS (6.33) and at harvest (19.35), the maximum leaf length (18.40 cm), the maximum leaf breadth (9.68 cm), the maximum leaf area (182.51 cm^2), the maximum transplanting to curd initiation (43.65 days), the maximum days required for 50% curd initiation (47.23 days), the maximum curd initiation to harvest (9.79 days), the maximum length of biggest leaf at harvest (41.51 cm), the maximum breadth of biggest leaf at harvest (12.28 cm), the maximum curd diameter (13.67 cm), the maximum pure curd weight (698.20 kg), the maximum curd weight with leaves (1.56 kg), maximum curd yield per plot (1.53 kg), the maximum curd yield per ha (15.30 ton) were recorded from the 2 kg zinc ha^{-1} that is B_3 treatment.

On the other hand, the shortest plant height at 30 DAS (12.97 cm), 50 DAS (22.36 cm) and at harvest (39.94 cm), the shortest number of leaves per plant at 30 DAS (4.87) and at harvest (17.44), the shortest leaf length (17.17 cm), the shortest leaf breadth (8.16 cm), the shortest leaf area (121.85 cm^2), the shortest transplanting to curd initiation (46.82 days), the shortest days required for 50% curd initiation (49.44 days), the shortest curd initiation to harvest (11.81 days), the shortest length of biggest leaf at harvest (40.97 cm), the shortest breadth of biggest leaf at harvest (11.73 cm), the shortest curd diameter (12.55 cm), the shortest pure curd weight (418.60 kg), the shortest curd weight with leaves (1.07 kg), shortest curd yield per plot (1.05 kg), the shortest curd yield per ha (10.49 ton) were recorded from the control treatment that is B_0 treatment.

In case of combined effect of zinc and boron, the highest plant height at 30 DAS (16.82 cm), 50 DAS (26.02 cm) and at harvest (44.50 cm), the maximum number of leaves per plant at 30 DAS (8.53) and at harvest (22.03), the maximum leaf length (21.17 cm), the maximum leaf breadth (12.71 cm), the maximum leaf area (275.57 cm^2), the maximum transplanting to curd initiation (43.33 days), the maximum days required for 50% curd initiation (46.57 days), the maximum curd initiation to harvest (10.03 days), the maximum length of biggest leaf at harvest (42.39 cm), the maximum breadth of biggest leaf at harvest (13.35 cm), the maximum curd diameter (16.79 cm), the maximum pure curd weight (765.35 kg), the maximum curd weight with leaves (1.59 kg), maximum curd yield per plot (1.65 kg), the maximum curd yield per ha (16.5 ton) were recorded from the 2.5 kg zinc $ha^{-1}$and 2 kg boron $ha^{-1}$and that is Zn_3B_3 treatment combination.

On the other hand, the shortest plant height at 30 DAS (11.50 cm), 50 DAS (20.17 cm) and at harvest (36.47 cm), the shortest number of leaves per plant at 30 DAS (3.33) and at harvest (15.71), the shortest leaf length (15.13 cm), the shortest leaf breadth (6.23 cm), the shortest leaf area (94.37 cm^2), the shortest transplanting to curd initiation (47.75 days), the shortest days required for 50% curd initiation (50.33 days), the shortest curd initiation to harvest (12.53 days), the shortest length of biggest leaf at harvest (40.09 cm), the shortest breadth of biggest leaf at harvest (11.02 cm), the shortest curd diameter (13.03 cm), the shortest pure curd weight (394.52 kg), the shortest curd weight with leaves (0.58 kg), shortest curd yield per plot (0.90 kg), the shortest curd yield per ha (9.0 ton) were recorded from the Zn_0B_0 treatment combination.

CONCLUSION

On the basis of results it was revealed that application of 2.5 kg Zn ha^{-1} and 2 kg boron ha^{-1} (Zn_3B_3) treatment combination performed the highest yield (16.5 ton ha^{-1}) of cauliflower. Considering the findings of the experiment, it can be concluded that Zn_3B_3 treatment combination is suitable dose for getting higher yield of cauliflower.

REFERENCES

Adhikari, R., Chhetri, T. B. and Baral, D. R. 2001. Assessment of the needs of the micronutrients for cauliflower. *Nepal J. Inst. Agric. Anim. Sci.,* **7**: 21-30.

Agarwal, A. and Ahmed, Z. 2007. Response of cauliflower (*Brassica oleoracea* var. *botrytis*) to micronutrients application in high altitude cold desert of Ladakh. *Indian J. Agric. Sci.,* **77**(2): 104-105.

Ahmed, M. 2007. Effect of application of micronutrients (boron) on vegetative growth and curd yields in cauliflower (*Brassica oleraceae* var. *botrytis* L.). *World J. Agric. Sci.,* **7**(2): 149-156.

Alam, M. N. and Jahan, N. 2007. Effect of nutrient management on the growth and yield of cauliflower (*Brassica oleracea* var. *cauliflora* L.) in calcareous soils of Bangladesh. *The Agriculturists*, **12**(2): 24-33.

Ali, M. H. and Sur, S. 2003. Impact on cauliflower and mustard to soil application of $ZnSO_4$ and borax in farmers field of project areas in west Bengal. *Indian J. Agric. Sci.,* **22**: 273-279.

Andrejiova, E., Bijarnia, H. S. and Dixit, V. S. 2011. Growth and yield of cauliflower as affected by sulphur and zinc. *Ann. Bio.,* **12**(2):232-234.

Balyan, D. S., Dhanker, S. B. and Shelpi, E. 2004. Effect of nitrogen and zinc on yield of cauliflower var. Snowball-16. *Haryana Agric. Univ. J.,* **24**(2-3): 88-92.

BBS, 2015. Year Book of Agricultural Statistics of Bangladesh, Statistics Division, Ministry of Planning, Govt. of the People’s Republic of Bangladesh. p. 58.

Banuelos, G. S., Hoffman, J. G. and Meck, D. W. 2000. Impact of salinity and zinc on zinc uptake in cauliflower. *Plant Soil Sci.,* **127**(2): 201-206.

BARC, 2006. Fertilizer Recommendation Guide. BARC, Farmgate, Dhaka. p. 94.

Batal, M. K., and Mullinix, B. G. 1997. Application of nitrogen, magnesium and boron affect on cauliflower curd yield and hollow stem disorder. *Asian J. Plant Sci.,* **32**(1): 75-78.

Baylan, S. D., Ruhab, S. B. and Joginder, S. 1995. Growth and yield of cauliflower variety Snowball-16 as influenced by phosphorus, nitrogen and zinc. *Haryana J. Hort. Sci.,* **17**(3-4): 247-254.

Batabyal, P., Tripati, K. and Mandal, A. R. 2015. Effect of boron application on growth and yield of cauliflower. *South Indian Hort. Sci.,* **19(**3-4): 219-222.

Bhagavatagoudra, K. H. and Rokhade, A. K. 2001. Effect of sources and levels of zinc nutrition on growth and yield of cauliflower and cabbage. *Karnataka J. Agric. Sci.,* **14**(3): 724-726.

Bijarnia, H. S. 2007. Growth and yield of cauliflower *(Brassica oleracea* var. *botrytis* L.) as affected by zinc. *Ann. Bio*., **12**(2): 232-234.

Chadha, K. L. 2003. Handbook of Horticulture. ICAR, New Delhi. p. 365.

Chaudhary, D. andMukharjee, S. 2016. Effect of boron and zinc concentration on growth and yield of cauliflower cv. Snow Ball-16. *Haryana J Hort. Sci.,* **28**(1-2):119- 120.

Chhipa, B. G. 2005. Effect of different levels of sulphur and zinc on growth and yield of cauliflower (*Brassica oleracea* var. *botrytis* L.) M.S. Thesis, S.K.N. College of Agriculture, Jobner, India. p. 82.

Chhonkar, V. S. and Jha, R. N. 2005. Effect of zinc and boron on growth, yield and quality of cauliflower *(Brassica oleracea). Indian J. Hort.,* **22**: 322-329.

Devi, B. S. and Prasad, A. 2012. Response of cole crops by applying boron. *Veg. Sci.,* **18**(1): 80-81.

Divrikli, U., Saracoglu, S., Soylak. M. and Elci, L. 2003. Effect of zinc on growth, yield and seed production of cauliflower Var. snowball-16. *Indian J. Agric. Res.,* **10**: 12- 125.

Dixit, P. S. and Islam, M. B. 2006. Response of cauliflower to boron in vegetable growing area of Palam valley. *Indian J. Soc. Soil Sci.*, **43**(2): 229-231.

Duraisami, V. P. and Sakal, R. A. 2005. Effect of combination of boron and zinc on yield, uptake and availability of micronutrients on cauliflower. *Madras J. Agric.,* **92**(10-12): 618-628.

FAO. 2011. Production year book. Food and Agriculture Organization of the United Nations, Rome, Italy. **55**(3): 144- 145.

FAO. 2014. Production year book. Food and Agriculture Organization of the United Nations, Rome, Italy. **55**(7): 429-432.

Farag, I. A., Naser, P. and Refai, M. A. 2012. Relationship between the boron and zinc in soil, fertilizer and plants. *Int. Hort. Res. J.,* **10**: 165-176.

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

Ghimire, J. 2001. Study on boron response on cauliflower var. snowball-16. *Int. Hort. Res. J.,* p.1.

Gomez, K. A. and. Gomez, A. A. 1984. Statistical procedure for Agricultural Research (2nd edn.). National Book Trust, New Delhi, India. Pp: 28-92.

Haider, E. A. 1991. Agro Ecological Region of Bangladesh. Land Resources Appraisal of Bangladesh Agricultural Development. *Plant Physiol.,* **35**: 426-439.

Hussain, M. J., Sirajul Karim, A. M., Solaiman, A. R. M. and Haque, M. M. 2012. Effect of nitrogen and boron on the yield and hollow stem disorder of broccoli. *The Agriculturists*, **10**(2): 36-45.

Iyengal, A. R. and Kibe, M. M. 1998. Response of tomato of zinc fertilization in a zinc deficit soil of Maharashtra. *Indian J. Agric. Sci*., **41**(8): 650-654.

Joshi, D. 1997. Soil fertility and fertilizer use in Nepal. Soil Sci. Div. Pp. 320-325.

Kant, U., Raj, P., Suresh, C. P. and Pal, P. 2013. Effect of micronutrient on growth and yield of cauliflower in Gangetic alluvial soil of West Bengal. *Indian J. Hort. Sci.,* **21**(1): 179-172.

Khadka, D., Shreeram, C., Gautam, D. and Yadav R. M. 2004. Response of cauliflower (*Brassica oleracea* var. *botrytis*) to the application of boron and nitrogen in the soils of Rupandehi District. *Nepal J. Agric. Res.*, **9**:56- 66.

Kibria, M. G., Rahman, M. A. and Hossain, M. M. 2004. Effect of boron and nitrogen on yield and hollow stem of cauliflower. *J. Soil Sci.,* **1**(3): 24-29.

Kotecha, A. V., Dhruve. J. J. and Vihol, N. J. 2011. Effect of foliar application of micronutrients and growth regulators on growth and yield of cauliflower (*Brassica oleracea* L. var. *botrytis*). *Asian J. Hort.,* **6**(2):381- 384.

Kotur, S. C. 1991. Synergistic effect of lime and boron on curd rot and curd yield of cauliflower (*Brassica oleracea* L. var. *botrytis*) on Alfisol soils. *Indian J. Agri. Sci.,* **68**(5): 268-270.

Kotur, S. C. 1992. Effect of season and boron application on yield of cauliflower. *Karnataka J. Agric. Sci.,* **62**(4): 286-288.

Katur, S. C. 1997. Nitrogen, boron interaction in cauliflower (*Brassica oleracea* var. *botrytis* L.) on Alfisol. *Indian Soc. Soil Sci*., **45**(3): 519-522.

Kotur, S. C. 1998. Standardization of foliar spray of boron for correction of brown rot and for increasing yield of cauliflower in Bihar plateau. *Indian J. Agric. Sci.,* **68**(4): 218-221.

Kuldeep, R., Batabyal, S., Dibyendu, S. and Biswapati, M. 2011. Critical levels of boron, zinc and manganese in soils for cauliflower (*Brassica oleracea* var. *botrytis* L.). *J. Plant Nutr.,* **38**(12): 163-164.

Kumar, D. R. and Malabasari, T. A. 2012. Effect of foliar spray of micronutrients (boron) on plant growth, yield and quality of cauliflower (*Brassica oleracea* L.). *Karnataka J. Agric. Sci.,* **3**: 21-27.

Lewis, P. H. 2000. Are three inter-relations between metabolic role of boron, synthesis of phytoalexins and curd development in cole crops. *New Phytol.,* **84**: 264-270.

Malewar, G. U. 2003. Micronutrient interactions in soil and plants. *Fert. News.,* **48**(5):43-45.

Maurya, A. N., Muthoo, A. K. and Kumar, A. 2006. Effect of some micronutrients on the growth, yield and quality of cauliflower. *Haryana J. Hort. Sci.,* **16**(1-2): 149-150.

Mehrotra, O. N. and Mishra. P. H. 1994. Micronutrient deficiency in cauliflower. *Urissa J. Hort.,* **5**: 33-39.

Mengel, D. J. and Kirby. E. A. 1999. The physiological role of boron in plants. *J. Plant Nutr.,* **6**(7): 563- 582.

Mitra, S. K. 1990. Nutrition of vegetable crops. S. K. Mitra and T. K. Bose (1st ed.). Nayaprokash, Calcutta, India. Pp. 133-14.

Moklikar, M. F., Gaines, T. P. and Muthukrishnan, C. R. 2015. Effect of micronutrients (Fe, Zn and B) on cauliflower. *South Indian Hort.,* **28**(1):14-20.

Moniruzzaman, M., Rahman, S. M. and Rahman, M. A. 2007. Effect of boron on yield and hollow stem of cauliflower and broccoli. *J. Soil Sci.,* **1**(3):24-29.

Mukhopadhayay, T. P. and Chattopadhyay, S. B. 1999. Yield and quality of cauliflower as influenced by added different levels of boron. *Bangladesh J. Agric. Res.,* **27**(1): 1-4.

Mukhopadhayay, T. P. and Jana, E. C. 2002. Boron, zinc and molybdenum in growth and yield of cauliflower grown in Trai region of West Bengal. *Indian J. Hort.,* **12**(2): 71-76.

Nayak, S. C. and Nandi, A. 2000. Performance of hybrid cauliflower (*Brassica oleracea* L. var. *Capitata*) as influenced by micronutrient application. *Veg. Sci.,* **35**(1):45-48.

Nahar, M. A., Alam, A. N. and Jahan, N. 2008. Effect of nutrient management on the growth and yield of cauliflower (*Brassica oleracea* var. *capitata*) in calcareous soils of Bangladesh. *Res. J. Agric. Bio. Sci.,* **3**(6): 858-865.

Nayanmoni, B., Shivchandra, T. and Gogoi, S. 2007. Effect of boron and molybdenum on production of early cauliflower (*Brassica oleracea* L. var. *botrytis*) cv. Pusakatki. *Veg. Sci.,* **34**(1): 86-88.

Pandey, S. N. and Sinha, B. K. 1999. Physiology revised edition. Vikas publishing house Pvt. Ltd. New Delhi. Pp. 444-445.

Pardeep, U. C., Pattanayak, N. B. and Das, C. 2006. A note on the effect of micronutrients on yield and quality of cauliflower in red soil of Urissa. *Urissa J. Hort.,* **18**(1-2): 62-64.

Phor, B. C., Hosamani, R. M. and Smitha, K. C. 1995. Effect of zinc on growth and yield components of cauliflower. *Karnataka J. Agric. Sci*., **21**(3): 428-430.

Parekh, S. J., Sharma, K., Karetha, T. K. and Kakade, D. K. 2003. Influence of zinc and iron on yield and quality of cauliflower (*Brassica oleracea* var. *botrytis* L.). *Asian J. Hort.,* **3**(2): 380-381.

Pizetta, D., Luiz, C., Fereira, M., Cruz, C. and Barbosa, J. 2005. Response of boron fertilization on broccoli, cauliflower and cabbage planted in sandy soil. *Brassilian J. Hort.,* **23**(1): 51-56.

Prabha, M. B, and Ranjan, D. P. 1999. Varietal seeing in cauliflower against boron deficiency in Chota Nagpur Region. *Indian J. Hort.,* **45**(3-4): 307-311.

Prasad, T. H. and Rai, C. H. 2008. Studies on growth, yield and quality of cauliflower (*Brassica oleracea*) as influenced by boron and molybdenum. *J. Plant Nutr.,* **39**(2): 167-169.

Praveen, S., Dharmendra, K. Patidar, T. and Omprokash, R. 2016. Role of foliar application of micronutrients (Zn and Fe) in vegetables. *Int. J. Farm Sci.,* **7**(2): 15-21.

Rafique, E., Rashid, A. and Bughio, N. 2001. Diagnoising boron deficiency in cauliflower and mustard by plant analysis and soil testing. *Commun.Soil Sci.,* **25**(17-18): 2282-2897.

Raghubanshi, J. D., Berger, K. S. and Truog, E. 2013.Response of NPK with boron on growth and curd yield of cauliflower. *Indian J. Hort.,* **7**(1-2): 77-85.

Rahman, M. T., Ahmad, S. and Saha, S. R. 1992. Yield of cauliflower as influenced by sulphur, boron and molydenum. *The Agriculturists,* **24**(1-2): 91- 95.

Rajawat, K. S., Rathore, J. S., Gajendra, S. and Bhanwarlal, J. 2014. Effect of different micronutrients on plant growth, yield and curd quality of cauliflower. *Int. J. Adv. Res.,* **4**(9): 321-323.

Ramchandra, E. 2011.Boron deficiency in Mississippi soils and plants. *American Soil Sci. Soc.,* Pp. 424- 426.

Randhawa, K. S. and Bhail. A. S. 2013. Effect of boron and molybdenum on cauliflower. *Indian J. Hort.,* **33**: 83-91.

Saha, M. R., Chugh, L. K. and Sridhar, K. 2010. Effect of boron on the yield and protein fractions of cauliflower. *Int. J. Agric.,* **18**: 87-91.

Saini, S. J., Dhaliwal, K. T. and Sharma, A. K. 1985. Effect of nitrogen, zinc and boron on growth, yield and quality content of cauliflower. *Haryana J. Agril. Sci.,* **1**(5): 42-47.

Salim, R., Subu, M. M. and Islam. 2000. Effect of root treatment of cauliflower, parsely and spinach plant with copper and Zn on plant growth. *J. Env. Sci.,* **30**(10): 2123-2132.

Sarma. S. K. and Pandita, M. L. 2005. Role of boron in curd yield, protein and ascorbic acid content in cauliflower. *Hyderabad J. Agric.,* **7**: 19-21.

Shalaby, E. F., Forghali, I. A. and Refai, M. A. 2014. Response of two cultivars of cauliflower to boron and zinc rates. *Australian J. Agric. Sci.,* **3**: 291-297.

Sharma, K. C. 2002. Influence of boron and molybdenum on production in cauliflower (*Brassica oleracea* L.). *Veg. Sci.***,** **27**(1): 62-63.

Shen, Y., Zhang, T. and Waong, H. 1996. A study of boron nutrition in relation to cauliflower crops. *Korean J. Hort. Sci.,* **19**: 61-63.

Shkolnik, M. J. 1999. Micronutrients in plant life of Nauka, Leningard, Russia. *Russian J. Hort. Sci.,* p. 323.

Shumiati. H. 2003. Response of cauliflower (*Brassica oleracea* L. var. *botrytis*) to nitrogen and zinc application. *Indian J. Agric. Sci.,* **16**(4): 14-23.

Shukla, V., Sengar, S. and Washeem, K. 2003. Response of cauliflower to plant spacing, boron and molybdenum. *Indian J. Hort.,* **52**: 315-321.

Singal, T. and Gautam, M. 1995. Micronutrient interactions and yield improvement of cauliflower. *Int. J. Agric.,* **6**: 25-32.

Singh, H. G. 1990. Effect of zinc on yield quality and their uptake by cauliflower, *Prog. Hort.,* **9**: 103-108.

Singh, N. P., Bhardwaj, A. K., Kumar, A. and Singh, K. M. 1992. Influence of boron and zinc and their combinations on the yield of cauliflower. *Asian J. Hort.,* **8**(1): 72-78.

Singh, S. B., Singh, T., Singh, B. N. and Singh, S. S. 1994. Growth and yield of cauliflower in relation to zinc and boron levels in hilly areas. *Haryana J. Hort. Sci.,* **18**(2): 113-118.

Singh, V. P., Yadav, A. C. and Thakral, K. K. 2003. Effect of zinc and boron on curd yield and quality of Indian cauliflower. *Veg. Res.,* **30**(2): 328-330.

Singh, S. and Singh, P. 2004. Response of cauliflower to the combination of nitrogen and zinc on growth and yield of cauliflower (*Brassica oleracea* L. var. *botrytis*). *J. Agric. Res.,* **13**: 123-128.

Singh, Y. V., Nitish, R. and Bhandari, R. C. 2011. Integrated boron management for cauliflower. *Indian J. Agric. Sci.*, **54**(7): 581-588.

Som, B., Maity, E. and Nazrul, I. 1986. Micronutrient interactions in soils and plants. *Asian J. Hort.*, **7**(4): 12-13.

Srihari, Z. and Tiwari, H. 1997. Response of cauliflower to zinc and boron fertilization. *Veg. Sci.*, **26**(1): 82-84.

Swain, H., Naser, T. M. and Varma, S. 2015. Effectiveness of soil application of boron on the yield of cauliflower. *J. Agric. and Food Sci.*, **2**(12): 246-251.

Thompson, L. M. and Troeh, F. 1957. The micronutrients. *Indian Soil Sci. Inst.,* Pp. 324-347.

UNDP. 1988. Land Resource Appraisal of Bangladesh for Agricultural Development Report 2: Agro-ecological Regions of Bangladesh, FAO, Rome, Italy. p. 577.

Varghese, C. and Annie, T. 2005. Impact of zinc and boron and their combinations on growth and yield on cauliflower. *Madras J. Agric.*, **31**(1): 64-65.

Verma, N., Indulkar, B. S. and Moore, K. P. 2003. Effect of micronutrients on curd yield. *Haryana J. Hort. Sci.*, **23**(2): 207-209.

Waring, B. and Theiler, R. 2003. Cauliflower and broccoli: growth pattern and potential yield. *German J. Agric*., **10**(7-9): 276-281.

Xin, Q., Gong, Y. and Chen, G. 1999. Growth and yield performances as influenced by boron application. *China Veg. Sci.*, **25**(12-15): 126-138.

Zhang, 2006. Effect of zinc and boron fertilization on cauliflower in calcareous cinnamon Soil. *China Veg. Sci.*, Pp. 9- 19.

Zhu, S., Jurikova, T., Slosar, M. and Kanujia, S. 2013. Selected yield and qualitative parameters of cauliflower, broccoli dependence on boron, sulfur, and zinc fertilization. *Turkish J. Agric.*, **40**: 465-473.

Zubair, M., Nawaz, H. and Derawadan, H. A. 2011. Interactive effects of nitrogen and zinc on growth and yield of cauliflower (*Brassica oleracea). J. Agric. Res.*, **8**(28): 322-326.

APPENDICES

Appendix I. Monthly temperature, rainfall, and relative humidity of the experiment site during the period from October 2016 to February 2017.

Year	Month	Air temperature (^{0}c) mean	Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
2016	October	28.42	77.35	209	210.8
	November	25.08	68.52	00	235.3
	December	22.64	72.67	00	212.7
2017	January	19.55	70.47	06	197.3
	February	24.45	63.07	04	225.8

Source: Bangladesh Meteorological Department (climate division), Agargoan, Dhaka.

Appendix II. Characteristics of Horticulture Farm soil is analyzed by Soil Resource and Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

A. Morphological characteristics

Morphological features	Characteristics
Location	Horticulture garden, SAU, Dhaka.
AEZ	Madhupur Tract (28)
Soil type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Mechanical analysis

Constituents	Percentage (%)
% Sand	29.20
% Silt	43.12
% Clay	31.04

C. Chemical analysis

Characteristics	Value
Textural class	Silty clay
pH	5.8-6.5
Organic carbon (%)	0.96
Organic matter (%)	0.78
Total N (%)	0.08
Available P (ppm)	20
Exchangeable K (me/100g soil)	0.10
Available S (ppm)	45
Available Zn (ppm)	4.78
Available B (ppm)	0.96

Source: Soil Resource Development Institute (SRDI)

Appendix III. Analysis of variance of data on plant height, number of leaves at different days after transplanting of cauliflower

Source of variation	Degrees of freedom (df)	Mean square				
		Plant height at 30 DAT (cm)	Plant height at 50 DAT (cm)	Plant height at harvest (cm)	No. of leaves at 30 DAT	No. of leaves at harvest
Replication	2	1.741	0.061	0.060	0.083	0.327
Factor A (Zinc)	3	33.893*	37.904*	108.619*	43.056	51.656*
Factor B (Boron)	3	4.195*	2.811*	6.818*	2.500*	4.239*
Interaction (A×B)	9	1.242*	0.126*	0.090*	0.074*	0.057**
Error	30	0.157	0.113	0.296	0.051	0.084

****:** significant at 1% level of probability. ***:** significant at 5% level of probability.

Appendix IV. Analysis of variance of data on leaf length, leaf breadth, leaf area, transplanting to curd initiation, days required for 50% curd initiation of cauliflower

Source of variation	Degrees of freedom (df)	Mean square				
		Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)	Transplanting to curd initiation (days)	Days required for 50% curd initiation
Replication	2	0.116	0.390	184.5	0.021	0.083
Factor A (Zinc)	3	45.376*	55.816**	39465.3**	38.799*	49.243*
Factor B (Boron)	3	3.364*	5.032*	3603.4*	3.076*	4.521*
Interaction (A×B)	9	0.219*	0.939**	712.5*	0.039*	0.401**
Error	30	0.499	0.178	110.4	0.265	0.328

****:** significant at 1% level of probability. ***:** significant at 5% level of probability

Appendix V. Analysis of variance of data on curd initiation to harvest, length of biggest leaf, breadth at biggest leaf at harvest, curd diameter, pure curd weight of cauliflower

Source of variation	Degrees of freedom (df)	Mean square				
		Curd initiation to harvest (days)	Length of biggest leaf at harvest (cm)	Breadth of biggest leaf at harvest (cm)	Curd diameter (cm)	Pure curd weight (g)
Replication	2	0.051	0.205	0.028	0.293	599
Factor A (Zinc)	3	6.441*	89.332*	31.149*	58.862*	2023.14*
Factor B (Boron)	3	0.051*	6.303**	2.116*	4.459*	1518.2*
Interaction (A×B)	9	0.012*	0.050*	0.011*	0.141*	351**
Error	30	0.003	0.062	0.028	0.013	57

****:** significant at 1% level of probability. ***:** significant at 5% level of probability.

Appendix VI. Analysis of variance of data on curd weight with leaves, curd yield plot^{-1}, curd yield ha^{-1} of cauliflower

Source of variation	Degrees of freedom (df)	Mean square		
		Curd weight with leaves (kg)	Curd yield (kg plot^{-1})	Curd yield (ton ha^{-1})
Replication	2	0.001	0.006	0.631
Factor A (Zinc)	3	1.678*	1.899*	189.874*
Factor B (Boron)	3	0.072*	0.088*	8.793*
Interaction (A×B)	9	0.006**	0.017**	1.682**
Error	30	0.001	0.002	0.162

****:** significant at 1% level of probability. ***:** significant at 5% level of probability.