EFFECT OF NITROGEN AND ZINC ON GROWTH AND YIELD OF TOMATO

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF NITROGEN AND ZINC ON GROWTH AND YIELD OF TOMATO"** submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **HORTICULTURE**, embodies the result of a piece of *bona fide* research work carried out by **S. M. KAMRUZZAMAN**, Registration No. **09-03531** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2016
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Dedicated To

My Beloved Parents

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ABSTRACT

A field experiment was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka during the period from October, 2015 to March, 2016 to study the effect of nitrogen and zinc on growth and yield of tomato. The treatments of the experiment consisted of four levels of nitrogen, viz. N_0: Control, N_1: 100 kg N ha^{-1}, N_2: 120 kg N ha^{-1}, N_3: 140 kg N ha^{-1} and three levels of zinc, viz. Zn_0: Control, Zn_1: 1 kg Zn ha^{-1}, Zn_2: 2 kg Zn ha^{-1}. The experiment was laid out in Randomized Complete Block Design with three replications. Due to the nitrogen application, the highest plant height (80.88 cm), number of leaves per plant (73.22), flower clusters per plant (10.93), fruits per cluster (6.48), Vitamin C (13.94 mg per 100g), fruit yield per hectare (66.15 ton) were recorded from N_2 treatment. In case of zinc application, the highest plant height (90.50 cm), leaves number per plant (76.16), flower clusters per plant (10.93), fruits per cluster (6.18), Vitamin C (14.84 mg per 100g), fruit yield per hectare (65.82 ton) were recorded from the Zn_2 treatment while the minimum is obtained from control treatment. In case of combined effect, N_2Zn_2 gave the highest plant height (99.00 cm), leaves number per plant (88.66), flower clusters per plant (14.93), fruits per cluster (7.93), Vitamin C (16.55 mg per 100g), fruit yield per hectare (76.68 ton), while the minimum yield per hectare (37.55 ton) was obtained from N_0Zn_0 treatment. From this study it can be concluded that, N_2Zn_2 treatment combination is suitable for higher yield of tomato.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

ABBREVIATIONS		ELABORATIONS
AEZ	:	Agro-Ecological Zone
ANOVA	:	Analysis of Variance
Adv.	:	Advanced
Agric.	:	Agriculture
Agril.	:	Agricultural
BRRI	:	Bangladesh Rice Research Institute
BARI	:	Bangladesh Agricultural Research Institute
BAU	:	Bangladesh Agricultural University
BBS	:	Bangladesh Bureau of Statistics
RCBD	:	Randomized Complete Block Design
CV	:	Coefficient of Variation
cv.	:	Cultivar
EC	:	Emulsifiable Concentrate
cm	:	Centimeter
df	:	Degrees of Freedom
DAS	:	Days After Sowing
LSD	:	Least significance difference
et al.	:	and others
etc.	:	etcetera
FAO	:	Food and Agriculture Organization
Fig.	:	Figure
J.	:	Journal
g	:	Gram
ha^{-1}	:	Per hectare
t	:	Ton
m^2	:	Square meter

ABBREVIATIONS		ELABORATIONS
Res.	:	Research
PS II	:	Photosystem II
RH	:	Relative humidity
WCE	:	Weed control efficiency
SRDI	:	Soil Resource Development Institute
HI	:	Harvest Index

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) belongs to the family Solanaceae, is one of the most popular and quality vegetable grown in Bangladesh. It was originated in tropical America, particularly in Peru, Ecuador and Bolivia. It is popular for its taste, nutritional status and various uses. Tomato is cultivated all over the country due to its adaptability to wide range of soil and climate (Ahmad and Chaudhry, 1976). It ranks third, next to potato and sweet potato, in terms of world vegetable production (FAO, 2002) and tops the list of canned vegetables (Choudhury, 1979). The crop is adapted to a wide variety of climates ranging from the tropics to a few degree of the Arctic Circle. It is now being cultivated successfully in tropical, subtropical and temperate climate. The present leading tomato producing countries of the world are China, United States of America, India, Egypt, Turkey, Iran, Italy, Mexico, Brazil and Indonesia (FAO, 2002).

The popularity of tomato and different products produced from tomato processing is increasing day by day. It is a nutritious and delicious vegetable used in salads, soups and processed into stable products like ketchup, sauce, marmalade, chutney and juice. They are extensively used in the canning industry for canning.

Nutritive value of the fruit is an important aspect of quality tomato and public demand. Food value of tomato is very rich because of higher contents of vitamins A, B and C including calcium and carotene (Bose and Som, 1990) and it keeps eye sight good. Night blindness occurs due to lack of Vitamin-A. Tomato contains lycopene pigment which is a vital anti-oxidant that helps to fight against cancerous cell formation as well as other kind of health complications and diseases (Kumavat and Chaudhari, 2013). Tomatoes are rich in Vitamin-K which plays a major role in blood clotting.

Nutritional value of red tomatoes (raw) per 100 g contains 18 kcal energy, 4.0 g carbohydrates, and 2.6 g sugars, 1.0 g dietary fiber, 0.2 g fat, 1.0 g protein, 95 g water, 13 mg vitamin C (Zhang *et al.,* 2009). Food value of tomato is generally dependent on its chemical composition such as dry matter, titratable acidity, total sugar, total soluble solids and ascorbic acids etc. Excellent nutritional and processing qualities have made tomato demandful in both domestic and foreign markets.

In Bangladesh, tomato has great demand throughout the year, but its production is mainly concentrated during the winter season. Recent statistics showed that tomato covered 75602 acres of land and the total production was approximately 413610 metric tons (BBS, 2015). Thus, the average yield of 5471kg/acre which is quite low as compared to that of other tomato producing countries. The low yield of tomato in Bangladesh, however, is not an indication of the low yielding potentiality of this crop, but of the fact that the lower yield may be attributed to a number of reasons, viz. unavailability of quality seeds of improved varieties, fertilizer management, disease infestation and improper moisture management. Among them fertilizer management is a vital factor that influences the growth and yield of tomato.

Among the different nutrients that were required for tomato cultivation nitrogen is most important nutrients. On the other hand, soils of Bangladesh have been deficient in nitrogen fertilizer. Nitrogen is an essential and important determinant for growth and development of crop plants (Tanaka *et al*., 1984). It is constituent part of proteins, the basis of life, the nucleic acids (RNA, DNA), chlorophyll, phosphamide and other organic compounds. Nitrogen is essential for building up protoplasm and protein, which induce cell division and initial meristematic activity when applied in optimum quantity (Singh and Kumar, 1969). It has the largest effect on yield and quality of tomato (Xin *et al.,* 1997). It also promotes vegetative growth, flower and fruit set of tomato. It significantly increases the growth and yield of tomato (Bose and Som, 1986).

Again adequate supply of micronutrients also plays an important role in tomato production. Tomato yield declines due to micronutrient deficiency (Ejaz *et al.,* 2011). Among the micro elements, Zinc is essential for normal plant growth and development as well as carbohydrates, protein metabolism and sexual fertilization of plant (Imtiaz *et al.,* 2003; Vasconcelos *et al.,* 2011). Zinc plays an important role directly and indirectly in improving the yield and quality of tomato in addition to checking various diseases and physiological disorders. Crops differ in their sensitivity to zinc deficiency. It gives a rosette appearance and yellowing between veins of new growing leaves occur in plant (Marchner, 1995).

In Bangladesh, there is limited information on the effect of nitrogen and zinc on growth and yield of tomato. In view of these limitations, a field experiment containing the treatments of nitrogen and zinc was conducted with the following objectives:

- To study the effect of nitrogen on growth and yield of tomato
- To estimate effect of zinc on growth and yield of tomato; and
- To identify the suitable doses of nitrogen and zinc fertilizer for better tomato production

Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Nitrogen and zinc are the most important nutrient elements for maximizing the yield of tomato. The proper fertilizer management essentially influences it's growth and yield performance. Experimental evidences showed that there is a profound influence of nitrogen and zinc fertilizers on this crop. The fertilizer requirements, however, varies with the soil and cultural conditions. Research works have been done in various parts of the world including Bangladesh is not adequate and conclusive. Some of the important and informative works conducted home and abroad in this aspect, have been furnished in this chapter.

2.1 Literature on the effect of nitrogen

Nawaz *et al.* (2012) conducted an experiment on interactive effects of nitrogen (N), phosphorus (P) and zinc (Zn) on growth and yield of tomato. Four levels of nitrogen (0, 100, 150 and 200 kg/ha), four levels of phosphorus (0, 60, 80 and 100 kg/ ha) and three levels of zinc (0, 5 and 10 ppm) were applied. The results pertaining to various growth and yield parameters showed that early flowering was observed when plots received phosphorus at 100 kg/ha and zinc at 10 ppm without nitrogen. In contrast, flowering was significantly delayed when plots received nitrogen alone at 200 kg/ha. The minimum disease incidence (3.67%) was recorded in plots applied with phosphorus at 100 kg/ha and zinc at 10 ppm without nitrogen. Maximum number of fruit per plant (41.67) was observed when plots received nitrogen at 150 kg/ha, phosphorus at 100 kg/ha and zinc at 10 ppm. Total yield (28.43 t/ha) was increased 100% as compared to control (13.44 t/ha) when plots received nitrogen at 150 kg/ha, phosphorus at 100 kg/ha and zinc at 10 ppm.

Kirimi *et al.* (2011) investigated the effects of nitrogen levels and spacing on tomato fruit yield and quality in two seasons. The first season commenced in October 2002, to February 2003, the second in February 2003, to July 2003.

The nitrogen rates 0, 40, 80 and 120 kg N ha^{-1} applied in two equal splits. Spacing was 40×30, 40×40, 50×30 and 50×40 cm. Number of marketable fruits was significantly affected by spacing in both seasons. Nitrogen of 80 kg ha^{-1} and spacing of 40×30 cm had the highest mean fruit numbers in season 2. Nitrogen of 80 kg N ha^{-1} and spacing of 50 × 30 cm had the highest fruit yield in season 1. Marketable unit fruit weight was highest in season 1, at 50 × 40 cm. The study was significant to farmers producing tomatoes under greenhouse, to maximize on profits by scaling down nitrogen fertilizer use to attain high yields and quality of marketable tomato fruits using appropriate spacing.

Balemi (2008) investigated the response of tomato cultivars varying in growth habit to rates of Nitrogen (N) and Phosphorus (P) fertilizers. Resulted in 2003/2004 cropping season showed that the application of 110 kg N + 120 kg P_2O_5/ha or 80 kg N + 90 kg P_2O_5/ha resulted in significantly higher total as well as marketable fruit yield of the tomato cultivars. However, demonstrated that only the application the highest fertilizer rate (110 kg N + 120 kg P_2O_5/ha) resulted in superior fruit yields whilst the other two rates did not significantly differ from each other in affecting fruit yields. Results of both cropping seasons confirmed significantly higher % marketable fruit yield due to the application of either 110 kg N + 120 kg P_2O_5/ha or 80 kg N + 90 kg P_2O_5/ha.

A field experiment was conducted at Bhubaneswar, India by Sahoo *et al.* (2002) to study the effects of nitrogen (50, 100, 150 or 200 kg N/ha) and potassium (75 or 150 kg K/ha) on the growth and yield of tomato var. Utkal kumari during the rabi season of 1999-2000.The wide range of variation was marked by the application of nitrogen with respect to growth, development and yield of tomato fruit. The fruit yield increased with each increase in the levels of nitrogen from 50 to 150 kg but further increased of nitrogen beyond 150 kg/ha reduced the yield considerably. They also found that the highest value relating to yield attributing characters like number of fruits per plant and single fruit weight were maximum when potassium was applied at the rate of 75 kg/ha. However, the combination of 150 kg N/ha along with 75 kg K/ha gave best result with respect to tomato from yield and other yield attributing characters.

Ceylan *et al.* (2001) conducted a field experiment to assess the effect of ammonium nitrate and urea fertilizers at 0, 12, 24, 36 kg N/ha on nitrogen uptake and accumulation in tomato plants under field [Turkey] conditions. The total nitrogen, NO_2-N and NO_3-N contents of leaves and fruits were determined. On the first and second harvest dates, the highest NO_3-N and NO_2-N amounts in tomato leaves and fruits were obtained upon treatment with 36 kg N/ha. Ammonium nitrate application increased nitrate and nitrite accumulation compared to urea application. The highest yield was recorded upon treatment with 24 kg N/ha.

Bot *et al.* (2001) carried out an experiment to evaluate the response of adult tomato plants growing in rock wool in a greenhouse to N withdrawal from the nutrient solution was studied over a 6-week period during fruit production. The major effect of N withdrawal included the impairment of growth of fast growing organs. Fruit growth was impaired, leading to a reduction in yield. The growth of young leaves was also inhibited. The stores of nitrate N were depleted after removal of N in the solution, but it took 45 days for the plants to metabolize completely their nitrate reserves.

Raghav (2001) conducted a field experiment evaluating two F_1 hybrids of tomato (Naveen and Vaishali), three plant spacings (75 cm × 50 cm, 75 cm × 75 cm and 75 cm × 100 cm) and four levels of nitrogen (0, 75, 150, 225 and 300 kg/ha) during 1995-96 and 1996-97 at the Research Station, Nagina of G.B. Pant University of Agriculture and Technology, Pantnagar (Uttar Pradesh, India) on sandy loam soil. Naveen F_1 hybrids gave significantly higher yield during both years, followed by Vaishali using closer spacing (75 cm × 50 cm). Among the various levels of nitrogen, 300 kg/ha was found to be best in improving the growth and yield of both cultivars.

Sainju *et al*. (2001) stated that cover crops can influence soil properties, fruit yield, and growth of above and below ground biomass of tomato (*Lycopersicon esculentum*). The influence of legume, i.e. hairy vetch (Vicia villosa) and crimson clover (*Trifolium incarnatum*), and non-legume, i.e. rye (Secale cereale), cover crops and N fertilizer application (0, 90, and 180 kg N/ha) on tomato yield, root growth, and soil N and C concentrations, were examined and compared. Hairy vetch, crimson clover and the application of 90 and 180 kg N/ha resulted in a greater increase in fruit yield, N uptake and biomass of tomatoes, compared with rye or 0 kg N/ha. The soil inorganic N at 48 days after transplanting (DAT) in 1996, and at 36 DAT in 1997, were greater with hairy vetch and 90 and 180 kg N/ha than with 0 kg N/ha. Rye increased tomato root growth relative to 0 kg N/ha due to higher biomass yield, and soil organic C and N levels.

Two field experiments were conducted in Egypt by Awad *et al.* (2001) to study the effect of intercropping parsley and demsisa with tomato under 4 rates of N fertilizer (100, 120, 140 and 160 kg N/fed). The results showed that increasing N fertilizer rate enhanced total yield and net assimilation rate (NAR) of both mono and mixed crops, earliness index of tomato and NPK uptake of tomato in NAR. Total yield, earliness index and N uptake. The best values were obtained by pure stand planting at the highest N rate (160 kg N/fed), whereas the best P and K uptake were attained at 140 and 120 kg N/fed, respectively. The highest value of N supplementation index (NSI) for tomato was obtained at 100 kg N/fed, whereas the highest values of phosphorus supplementation index (PSI) and potassium supplementation index (KSI) were recorded by plants which received 160 kg N/fed.

A field study was undertaken by Khalil *et al.* (2001) in Peshawar, Pakistan in the summer of 1995-96 to determine the appropriate nitrogen fertilizer for maximum tomato (cv. Peshawar Local) yield and its effects on various agronomic characters of tomato. Treatments comprised: untreated control; 150 kg ammonium nitrate/ha; 150 kg ammonium nitrate/ha + 100 kg P/ha + 50 kg

K/ha; 150 kg ammonium sulfate; 150 kg ammonium sulfate/ha + 100 kg P/ha + 50 kg K/ha; 150 kg urea/ha; 150 kg urea/ha + 100 kg P/ha + 50 kg K/ha. Generally, ammonium sulfate fertilizer was the most efficient source of nitrogen for tomato production, followed by urea and ammonium nitrate. The ammonium sulfate + P + K treatment was the best among all treatments with respect to days to flower initiation (57 days), days to first picking (94 days), weight of individual fruit (50.8 g), weight of total fruits per plant (1990 g) and yield (21865 kg/ha). The control resulted in the significantly lowest response with respect to different agronomic characters under study.

Ravinder *et al.* (2000) conducted an experiment at Solan in 1996 and 1997, eight tomato hybrids (Meenakashi, Manisha, Menka, Solan, Sagun, FT-5XEC-174023, EC-174023XEC-174041, Rachna and Naveen) were treated with four NPK combinations (100:75:55; 150:112.5:82.5; 200:150:110; 250:187.5:137.5 kg N:P_2O5:K_2O ha^{-1}). The number of marketable fruits per plant and yield per plant were highest in Menka followed by Manisha. Of the fertilizers treatments, 200:150:110 kg N:P_2O_5:K_2O ha^{-1} produced the highest yields.

An experiment was conducted by Default *et al.* (2000) in Charleston, South Carolina, to determine (1) if supplemental nitrogen (N) at 60 or 120 kg/ha following winter cover crops of wheat. Tomato (*Lycopersicon esculentum* Mill.) and snap bean (*Phaseolus vulgaris* L.) grown in rotation; and (2) the distribution and retention of soil nitrates in the soil profile as affected by N fertilization and cover cropping, Total marketable tomato yield increased as fertilizer N increased to 60 kg/ha in two out of four years and with 120 kg/ha in one out of four years. In all cover crop or fallow plots, as fertilizer N application levels increased, the soil nitrates also increased.

Faria *et al.* (2000) reported that rates and periods of application were studied for application of N via drip irrigation to processing tomatoes (cv. IPA-5) growing in sandy soil in Petrolina, Brazil, during 1993-94. The N rates tested were: a total of 45, 90 or 135 kg N/ha applied daily for up to 25, 50 or 75 days after transplanting. Application of N in irrigation water was more efficient than soil application. In 1993, yields were highest (73.43 t/ha) with N at 90 kg/ha applied daily for 75 days after transplanting, whereas in 1994, yields were highest (67.86 t/ha) with N at 90 kg/ha applied daily for 50 days after transplanting. The lower yields obtained in 1994 were attributed to soil compaction following the earlier experiment. Application of N for only 25 days after transplanting generally gave poor yields.

Gupta and Sengar (2000) reported that tomato cv. Pusa Gaurav was treated with N at 0, 40, 80 and 120 kg/ha and K at 0, 30 and 60 kg/ha in a field experiment conducted in Madhya Pradesh, India during rabi 1992-93 and 1993-94. N application resulted in increases in plant height, number of fruits per plant, fruit weight and fresh yield. Increasing N rate produced a corresponding increase in yield and yield components, except total soluble solids (TSS) content. K increased vegetative growth, yield and TSS content. Increasing K rate up to 60 kg/ha increased growth parameters like plant height, and also increased fruit weight and marketable yield.

Hoffland *et al.* (2000) conducted an experiment to study how nitrogen availability affects within plant allocation to growth and secondary metabolites. Tomato plants were grown at six levels of 'nitrogen availability. When nitrogen availability increased, plant relative growth rate increased, but tissue carbon/nitrogen ratio in the second oldest true leaf and allocation to large glandular trichomes as well as to the defense compounds rutin, chlorogenic acid decreased but leaf protein concentration increased.

This study was conducted by Chang *et al.* (2000) to investigate the effect of nitrogen supply by NH_4N deposit fertilizer on plant growth and nitrogen uptake of tomatoes. NH_4N deposit fertilizer was applied using the "CULTAN" (Controlled Uptake Long Term Ammonium Nutrition) method. It was prepared by mixing one-third ammonium sulfate and two-thirds urea as nitrogen sources and by combining gypsum as a binder and loamy soil and compost as diffusion regulators in the beaker. In the first experiment, the application of NH_4N, deposit fertilizer with 7.5 g gypsum as a binder resulted in increased tomato fruit yield and nitrogen uptake efficiency compared to control. In the second experiment, the application of NH_4N deposit fertilizer with loamy soil and compost as a diffusion regulator and adjusted C/N ratio to 16 also resulted in increased nitrogen uptake of fruits.

Scholberg (2000) conducted an experiment and on growth analysis of field grown tomato for a number of Florida (USA) locations and management systems is presented here. Severe N stress resulted in fewer and smaller, but thicker, leaves. With increasing N, average leaf area index increased from 0.75 to 3.0, but radiation use efficiency (RUE) typically increased less than 30%. Lower RUE under N limited conditions reflected a decrease in N concentration of the most recently matured leaves from 40 mg/g to as little as 15 mg/g. Over the life of well- fertilized crops. Leaf N concentrations dropped from 55 to 65 mg got during initial growth to 20 to 35 mg/g at final harvest. Corresponding N concentrations for fruit and for stems were 30 to 35 mg g-I and 15 to 25 mg/g. Severe N stress affected leaf and stem N concentrations most drastically, whereas N in fruits was less variable.

Felipe and Casanova (2000) investigated that the effects of N (0, 90, 180 and 270 kg/ha), P (P_2O_5, 0, 135, 270 and 405 kg/ha), and K (K_2O, 0, 90, 180 and 270 kg/ha) on the yield and number of fruits of tomato were investigated in the field in Venezuela. The best treatment, with the highest yield and number of fruits per plant, was 180 kg N, 270 kg P_2O_5, and 180 kg K_2O/ha. It was possible to decrease the application of nutrients, particularly P. The increased yield was not due to larger fruits, but to an increase in the number of fruits. N had a profound effect on the number of fruits.

Field studies, on Pellic Vertisol in Cyprus, were designed by Papadopolos *et al.* (2000) to investigate the response of drip-irrigated tomato to conventional soil P fertilizer application as Triple Superphosphate (TSP) and fertigation when P is applied in the form of Urea Phosphate (UP), Monoammonium Phosphate (MAP) or Diammonium Phosphate (DAP). The N and P applied in soil were 300 and 94 kg/ha. An equivalent amount of P and an amount of 70 kg P/ha in a combination with 150, 300 and 450 kg N/ha were applied with irrigation water at a total amount of 200 mm of water. The K applied was 450 kg/ha in all treatments.

This investigation was carried out by Hafidh (2000) consisted of 2 experiments regarding the early growth of tomato (cv. Rio Grand), carried out during spring seasons of 1994 and 1995 in Libya. The first experiment considered the effect of early N application (0, 50, 100, 150 and 200 mg/litre) to seedlings, while the second one investigated plant response to N (100 mg/litre) applied after transplanting in relation to seedling age (1, 2, 3 or 4 weeks old). Results indicated that there were no significant effects of early N application on growth regardless of concentration. Vegetative growth characteristics were significantly lower in plants grown with N in comparison with those grown without it. In older seedlings, stem length, and fresh and dry weight of 2-week-old plants grown with N were significantly higher than those of 3- and 4-week-old transplants.

Singh *et al.* (2000) conducted an experiment in Uttar Pradesh, India, to determine the suitable rate and application method of N fertilizers for obtaining optimum growth and yield of tomato cv. Pusa Hybrid-2. N was applied at 40 kg/ha basal, 40 kg/ha top dressing, 80 kg/ha in 2 splits (40 kg/ha basal + 40 kg/ha top dressing), 50 kg/ha in 2 splits (40 kg/ha basal + 10 kg/ha foliar), 60 kg/ha (40 kg/ha basal + 20 kg/ha foliar), 70 kg/ha (40 kg/ha basal + 30 kg/ha foliar) and 80 kg/ha (40 kg/ha basal + 20 kg/ha top dressing + 20 kg/ha foliar). N at 80 kg/ha applied in 3 splits produced the highest yield and biomass. Increasing N rates resulted in increasing biomass and yield.

Duraisamy *et al*. (1999) reported that four rates (0, 50, 75 and 100%) of recommended N, A. brasilense culture (applied by dipping seedling roots in 200 g/10 litres, or soil application of 2 kg/ha), composted coir pith (CCP, 12.5 t/ha) and farmyard manure (FYM, 12.5 t/ha) were applied to rainfed tomatoes (cv. Paiyur-1) in a field experiment in India [date not given]. Fruit yield was higher in crops supplied with organic fertilizers (A. brasilense, CCP and FYM) than those supplied with inorganic N. Among the organic fertilizers, CCP resulted in the highest fruit yield (14.68 t/ha). Brix and acidity were not significantly affected by organic or inorganic fertilizer treatment. 75% N + CCP resulted in the highest cost:benefit ratio (1:9.92).

Rhoads *et al.* (1999) carried out an experiment to evaluate the influence of N rates and ground cover following tomato on soil nitrate-N movement was monitored in spring and fall [autumn] crops grown at the Florida A & M University, Florida, USA. Nitrogen rates varied from 0 to 360 lb/acre in the spring crop and from 0 to 600 lb/acre in fall tomato. Yield ranged from 1900 to 2600 boxes/acre in spring tomato, and from 1300 to 2700 boxes/acre in fall tomato. Fertilizer N rates above, 80 lb/acre were excessive, as shown by yield and residual soil nitrate-N levels. Residual soil nitrate-N was proportional to N application rate. Soil nitrate-N concentration following harvest was highest in the 1 to 3 ft depth range for spring tomato and the 2 to 4 ft depth range for fall tomato.

Hoffland *et al.* (1999) conducted an experiment on tomato plants with varying N availability were grown by adding N daily in exponentially increasing amounts to a nutrient solution at different rates. Leaves of plants grown at low N availability had a high leaf C : N ratio (21 g/g). The level of soluble carbohydrates correlated positively with susceptibility independent of the growth method. It is therefore suggested that the effect of N availability on susceptibility can be explained by variation in levels of soluble carbohydrates which hence may play a role in the infection process.

Hossain and Mohanty (1999) found in trials at Bhawanipatna, Orissa, India over 3 years (1995-1997), tomato, cv. Punjab Chhuhara, plants growing in a clay soil (pH 6.5) were supplied with 0-90 kg N/ha and 0-60 kg K/ha. Application of 90 kg N/ha and 40 kg K/ha resulted in the highest fruit weight (58.0 g) and total yield (341.9 q/ha).

Sharma *et al.* (1999) conducted a field experiment involving 4 levels of nitrogen (100, 150, 200 and 250 kg N/ha), 3 levels of phosphorus (60, 120 and 180 kg P_2O_5/ha) and 3 tomato hybrids (Naveen, MTH-16 and Rupali) and a local cultivar (Solan Gola) was conducted at Solan, India, to study the response of tomato hybrids to N and P. All the hybrids gave significantly higher total fruit yields than the local cultivar. Naveen recorded the greatest total fruit yield, while remaining statistically at par with MTH-16 and Rupali. Application of 200 kg N/ha resulted in significantly greater fruit size and mean fruit weight, compared to the other application rates. A significant improvement in plant height, fruit size and total fruit yield was observed with the application of phosphorus from 60 to 180 kg P_2O_5/ha.

Singh and Sharma (1999) stated that, five tomato varieties were grown under different fertility levels (0, 150, 200 and 250 kg N/ha). Half of this was applied at transplanting time and the second half as two top dressings at 45 days after transplanting and after first fruit picking. Information on 6 yield components was recorded. Plant height, number of leaves, number of first order laterals, percentage fruit set, fruit weight and yield increased with increasing N level. Ajanta gave the best yields. High ammonium nitrogen (NH_4N) concentration in solution may adversely affect greenhouse tomato yield, but it has been reported that small NH_4N fractions improve yield and may increase vegetative growth and nutrient element uptake.

A field study was conducted by Sandoval *et al.* (1999) to determine the tomato yield response to 0 : 100, 10 : 90, 20 : 80, 30 : 70, and 40 : 60 NH_4N : $N0_3N$ ratios supplied at the vegetative, vegetative plus flowering, flowering plus fruiting, and fruiting stages, and over the entire plant life cycle. Neither the length of NH_4N supply nor the NH_4N concentration in solution affected tomato yield. Plant height was not affected by NH_4N concentration in either the winter or spring experiments, and neither was fruit firmness measured for fruit at the mature green stage. Fresh and dry weights were unaffected by NH_4N concentration.

Bellert *et al.* (1998) studied the effects of low and high water vapor deficit regimes and electrical conductivities of 3.8 or 4.8 ms/cm on the growth and N uptake of 7-month-old tomatoes in NFT were investigated for 3 months. Growth and N uptake were not modified by the treatments. N accumulated in the aerial biomass in proportion to the dry matter. Total N concentration of the foliage was relatively constant and richer than that of vascular organs and fruits. A model is proposed to link total N concentration to dry matter accumulation.

A field experiment was conducted by Manoj and Raghav (1998) to evaluating two F_1 hybrids of tomato, three plant spacing (75 cm × 50 cm, 75 cm × 75 cm and 75 cm × 100 cm) and four levels of nitrogen (0, 75, 150, 225 and 300 kg/ha) was conducted during 1995-96 and 1996-97 at the Research Station, Nagina of G.B. Pant University of Agriculture and Technology, Pantnagar (Uttar Pradesh, India) on sandy loam soil. Among the various levels of nitrogen, 300 kg/ha was found to be best in improving the growth and yield.

Four experiments were conducted by Barakart and Gabr (1998) during the 1996 and 1997 autumn seasons, in El-Bostan district of Egypt on newly reclaimed sandy soil. The effects of inoculating with non-symbiotic N_2-fixing bacteria of the genera Azotobacter, Azospirillum and Klebsiella alone (single biofertilizers) or together (mixed biofertilizer) on tomato cv. Castle Rock seedling growth were examined. The effects of also applying N fertilizer at 0, 50, 100 or 150 kg/feddan on growth, fruit yield and chemical composition of tomato plants were also studied. Results revealed that tomato seedling growth was greatly improved by inoculation with the single or mixed biofertilizer. Total fruit yield was highest in both years when plants were inoculated with a mixture of the three genera of N_2-fixing bacteria and 100 kg N/feddan was applied. [1 feddan= 0.42 ha.]

Banerjee *et al.* (1997) stated that the effects of N fertilization (0, 75, 100 or 125 kg N/ha) and planting pattern (60 × 30 or 60×45 cm with single side planting, or 60×45, 60 × 60 or 90 × 45 cm with both side planting, accommodating 36, 24, 45, 33 and 30 plants/plot (3.6 × 1.8 m), respectively) on fruit yield of tomato cv. Hisar Lalima (Sel-18) were studied in Hisar, India, during rabi [winter] seasons of 1990-91, 1991-92 and 1995-96. Total fruit yield/plant and q/ha were significantly influenced by both N and planting treatments. The highest total fruit yield/plant (g) was recorded from treatments of 125 kg N/ha and spacing of 90 × 45 cm in 1991-92 and 1995-96, 125 kg N/ha and spacing of 60 × 45 cm (single side planting) in 1990-91. The lowest yields were recorded from the treatment combination of no N and a spacing 60×45 cm (single side planting) in all years. The highest total fruit yield (q/ha) was obtained from a treatment combination of 125 kg N/ha and a spacing of 60 × 45 cm (both side planting).

Kishan *et al.* (1997) found in a field trials in 1996-97 on a clay loam soil at Port Blair, India, tomato cultivars ‘NDT-3’, ‘NDT-44-1’, ‘AVT-2 JT’, ‘Selection-10’ and ‘Phule-16’ were given 0, 60, 90 or 120 kg N/ha (half at transplanting and half at 1 month after transplanting). ‘NDT-3’, ‘NDT-44-1’ and ‘AVT-2 JT’ took significantly fewer days to 50% flowering than ‘Selection-10’ and ‘Phule-16’. ‘Phule-16’ produced fruits with greatest length, breadth and weight, which resulted in significantly higher yield (208.5 q/ha) than the other cultivars. Nitrogen application significantly increased plant height and number of branches per plant compared to the control treatment. Application of 90 or 120 kg N/ha gave significantly larger and heavier fruits, and significantly higher tomato yields, than the other treatments. It is suggested that cultivars ‘Phule-

16' and 'AVT-2 JT' given 90 kg N/ha are suitable for cultivation in Andaman and Nicobar Islands.

Pandey *et al.* (1997) conducted a trials at Jabalpur, India in rabi [winter] 1981, tomato cultivars 'Acc-99' and 'Sweet-72' were given 0, 40, 80 or 120 kg N and 0, 40 or 80 kg P/ha. Fruit yields increased as N rate increased up to 80 kg/ha and as P rate increased. Overall, fruit yield was highest (499.5 q/ha) in 'Acc-99' given 80 kg N + 80 kg P/ha.

Adjanohoun *et al.* (1996) conducted an field trials on a red ferrallitic soil in northern Havana in 1994-95, tomato cv. 'Campbel1-28', plants were fertilized with 0, 60, 120, 180 or 240 kg N/ha, starting 38 days after sowing. Although increasing rates of applied N had no effect on average fruit weight, they significantly increased fruit numbers although application of 240 kg N/ha was excessive and significantly reduced yield compared with 120 or 180 kg N/ha (the highest yield, obtained with 180 kg N/ha, was 38 t/ha), A mathematical expression describing the curve of yield response is presented, and from it the optimum application rate was determined to be 158 kg N/ha, giving a fruit yield of 38.9 t/ha.

Hohjo *et al.* (1995) The tomato cv. Momotaro was grown using the nutrient film technique (NFT) in 1/2- and 3/4- to full-strength Enshi shoho balanced feed. In the first experiment, nutrient solutions were adjusted to contain $N0_3N$: NH_4N ratios of 10:0, 9:1 and 8:2. Shoot and root FW were increased by an increasing proportion of NH_4N with both strengths of solution, whereas Ca and Mg uptake were decreased by an increasing proportion of NH_4N only with the higher solution strength. Total yield was reduced by increasing the proportion of NH_4N, particularly with the higher strength of solution, a combination that also caused a marked increase in the incidence of blossom-end rot (BER). In the second experiment, $N0_3N$: NH_4N ratios of 10:0 and 8:2 and Ca concentrations of 2, 4 and 6 meq/litre were used.

Sharma (1995) stated that effects of N (30, 60, 90 or 120 kg/ha), P (30 or 60 kg P_2O_5/ha) and K (30 or 60 kg K_2O/ha) on seed production by tomato (cv. Solan Gola), growing in Himachal Pradesh, were investigated. Plant height, fruit number, seed yield/plant and seed yield/ha increased with increasing rates of N and P. The highest yields of seeds were observed in the presence of 120 kg N/ha and 60 kg P_2O_5/ha (189 and 154 kg/ha, respectively). Plant height, fruit number, seed yield/plant and seed yield/ha decreased with increasing rates of K; the highest seed yield (172 kg/ha) was observed at 30 kg K_2O/ha.

Field experiments were conducted by Huett (1993) with tomato cv. Flora-Dade on krasnozem soils to examine the effects of N (less than or equal to 420 kg/ha) and K (less than or equal to 120 kg/ha) on fruit yield and quality and leaf nutrient composition. The yield and quality of fruits at all sites was not affected by N or K fertilizer rate. Marketable yield was 83-118 t/ha and fruit firmness (compression) was 0.97-1.27 mm. These results indicate that the application of supra-optimal rates of N and K to semi-determinate fresh market tomatoes of cv. Flora-Dade is not detrimental to yield, composition or fruit firmness. For a 70 t/ha crop, 130 kg N/ha and 208 kg K/ha are equivalent to the amounts removed by fruits.

Oikeh and Asiegbu (1993) reported that four organic manures and NPK fertilizer, each at 4 rates, were assessed under field conditions for their comparative effects on tomato (cv. Rossol VFN) growth and yield. Fruit yields were best with swine or poultry manure applied at 10 t/ha (yields of 49 and 47 t/ha, respectively). Yields of 42-47 t/ha were obtained with sewage sludge or rabbit manure applied at 20 t/ha, while with NPK the best yield (35 t/ha) was obtained with 100 kg N + 40 kg P + 100 kg K/ha.

Trpevski *et al.* (1992) carried out in trials with 3 N was applied at 0, 40, 80 or 120 kg/ha to soil manure with 40 t FYM/ha in early spring. The 2 higher N rates increased the yield of San Pjer but reduced the yield of the other 2 cultivars. The effects of treatments on fruit N, dry matter, organic acid and vitamin C contents were generally not significant.

A study was carried out by Ahmad and Chaudhry (1990) on tomato cv. Roma V.F. at Maidugari, Nigeria, during 1986-87. N (as urea) was applied at 0, 40, 80, 120, 160, 200 and 240 kg/ha, in two equal doses at 2 and 5 weeks after transplanting. K at 30 kg/ha and P at 60 kg/ha were applied to the soil before transplanting. Flowering time was delayed with increasing rates of N, from 26 days in the control (zero N) to 45 days at 240 kg N/ha. Yield parameters, including number of fruits set, number of fruits harvested, individual fruit weight and fruit weight/plant, showed gradual increases reaching peaks at 200 kg N/ha, beyond which the yield potential showed a downward trend. The highest yield (47.6 t/ha) was obtained with application of 200 kg N/ha compared with only 9 t/ha for the control.

An experiment were conducted by Kooner and Randhawa (1990) at Punjab Agricultural University, Ludhiana to study the interaction of rates and sources of N with cultivars on the yield and processing quality of tomatoes in winter and spring seasons. Four rates of N (50, 100, 150 and 200 kg/ha) were applied as 2 sources, calcium ammonium nitrate (CAN) and urea, in a randomized, split plot design. PC produced significantly higher yields (222.7 kg/ha) than PK (208.9 kg/ha) in the spring planting while in the winter planting OS (163.9 kg/ha) and CS (113.9 kg/ha) were the best. Yields increased linearly with increasing N rate up to 150 kg/ha and CAN was the best source of N. TSS, juice percentage, ascorbic acid content and titratable acidity increased with increasing N up to 150 kg/ha.

Hegde and Srinivas (1989) carried out 2-years field trials at Hessaraghatta, Bangalore, with the cultivar Arka Saurabh, plants receiving N at 0, 80, 160 or 240 kg/ha were irrigated at 4 soil matric potentials (-25, -45, -65 and -85 kPa at 15 cm depth). Data are tabulated on plant height, number of shoots/plant, fruiting clusters/plant, DM production, root weight, number of fruits/plant, fruit weight, marketable yield, spoilage, total yield, fruit quality, and water use efficiency. The highest yields generally over the 2 years (493.0-610.0 q/ha) were obtained with N at 160 kg/ha and irrigation at -65 kPa.

Grela *et al.* (1988) reported that nitrogen was applied at 0, 8, 160 or 240 kg/ha to tomato cultivars ‘Campbell 28’, ‘Petomech’ and ‘Roma VF/P-73’ at a planting density of 1 or 2 plants/hole. Plant height, and the number of leaves, flowers and roots per plant increased with increasing N rates up to 160 kg/ha, and then decreased. The higher planting density produced taller plants and more leaves but fewer flowers and roots per plant.

In a study on the effect of nitrogen fertilization and plant intensification, Midan *et al.* (1985) observed that increasing nitrogen rates linearly increased the number of fruits per plant. However, medium and higher nitrogen rates gave best total yields. With different nitrogen rates, three times of application improved fruit per plant weight and total yield.

Patil and Bojappa (1984) conducted an experiment to study the effects of cultivars and graded levels of nitrogen and phosphorus on certain quality attributes of tomato. The experiment consisted of the cultivars ‘Pusa Ruby’, ‘Sious’ and ‘Sweet-72’. The plant received nitrogen at 70, 110 and 150 kg/ha and phosphorous (P) at 44 or 61.6 kg/ha with basal dressing of potassium (K) at 49.8 kglha and FYM at 25 t/ha. The highest fruit content of total sugars and next highest dry matter content were in sweet-72 while juice percentage was highest in pusa Ruby. Rising nitrogen rates increased fruit total increased fruit total sugars and juice percentage but decreased the dry matter content. Phosphorous had no appreciable effect as any of the indices studied.

Belichki (1984) reported that nitrogen was the most important nutrient. Flower and fruit numbers per plant were increased by nitrogen up to 240 kg/ha and fruit size was greatest 120 kg/ha.

Staneve (1983) conducted an experiment to investigate the effect of nitrogen supply on photosynthesis, leaf area and total dry matter in tomato and found that photosynthesis was inhabited by N deficiency. Leaf development and dry matter accumulation were greatest at 10meq/L N and declined at higher concentrations.

2.2 Literature on the effect of zinc

Zinc plays a fundamental role in several critical functions in the cell such as protein metabolism, gene expression, structural and functional integrity of biomembranes and photosynthetic carbon metabolis. Some of metabolic changes brought about by Zn deficiency could be well explained by the function of Zn as a structural component of a special enzyme or involvement in specific steps in particular metabolic pathways. However, there are changes in the synthesis and metabolism of Zn-deficient plants that could not be explained directly by the presence of Zn in the metabolic pathway or enzyme structure. Such responses are regarded to be rather indirect effects of Zn deficiency. Concerning the central role of Zn in stability of biomembranes and proteins. Zn deficiency can affect the photochemical processes in the thylakoids, and thus inhibits biophysical processes of photosynthesis. The flow of electrons through PSII is indicative of the overall rate of photosynthesis and is an estimation of photosynthetic performance.

Sultana *et al.* (2016) said that, the tomato yield and its contributing yield traits were significantly affected by foliar fertilizer treatments as against soil application of B and Zn fertilizers. Among various treatments, foliar application of Zn (0.05 %) + B (0.03%) produced maximum fruit yield (85.5 and 81.7 t ha^{-1} in 2013 and 2014, respectively) while the control no application of Zn (0.0) and B (0.0) produced 66.8 and 60.7 t ha^{-1} in 2013 and 2014, respectively and it was statistically identical with soil application of B and Zn @ 2 and 6 kg ha^{-1}, respectively. The increment of yield was 19.2 to 31.1% and 7.57 to 18.3%, respectively, over control and soil application. The integrated use of foliar application of micronutrients and soil application of macronutrients are recommended to enhance tomato yield.

Ali *et al.* (2015) reported that, to increase the yield of BARI hybrid tomato 4, cultivated in summer season of Bangladesh, foliar application of zinc and boron [T_0: control; T_1: 25-ppm $ZnSO_4$ (Zinc Sulphate); T_2: 25-ppm H_3BO_3 (Boric Acid) and T_3: 12.5-ppm $ZnSO_4$ + 12.5-ppm H_3BO_3] was done. Maximum plant height (106.9 cm), number of leaves (68.9/plant), leaf area (48.2 cm^2), number of branches (11.9/plant), number of clusters (21.6/plant), number of fruits (1.8/clusters and 33.6/plant), fruit length (5.3 cm), fruit diameter (5.1 cm), single fruit weight (60.4 g) and yield (1.9 kg/plant, 25.7 kg/plot and 58.3 t/ha) were found from foliar application of 12.5-ppm $ZnSO_4$ + 12.5-ppm H_3BO_3 while minimum from control. Early flowering (49.3 days) and minimum diseased infested plant (9.4%) were also found from foliar application of 12.5-ppm $ZnSO_4$ + 12.5-ppm H_3BO_3. Combined foliar application of zinc and boron was more effective than the individual application of zinc or boron on growth and yield for summer season tomato (BARI hybrid tomato 4).

Harris and Mathuma (2015) conductd an experiment to study the effects of foliar application of boron, zinc and their combinations on growth and yield of tomato cv. Thilina. Treatments; T_1-(B 150 ppm), T_2-(B 250 ppm), T_3-(B 350 ppm), T_4-(Zn 150 ppm), T_5-(Zn 250 ppm), T_6-(Zn 350 ppm), T_7-(B 150 ppm + Zn 150 ppm), T_8-(B 250 ppm + Zn 250 ppm), T_9-(B 350 ppm + Zn 350 ppm) and T_{10}- Control. The results revealed that foliar application of Zn alone at 250 ppm resulted in the maximum plant height, total dry weight, number and fresh weight of fruits/ plant. Foliar application of B at 250 ppm increased dry weight of leaves/ plant and dry weight of stem/ plant, and dry weight of roots/plant were high in both B at 250 ppm and Zn at 150 ppm. In all parameters, the lowest performance was recorded in the control treatment. The results also revealed that under the conditions in the experiment, yield could be increased by the application of Zn at the rate of 250 ppm at flowering stage.

Ullah *et al.* (2015) reported that among different levels of Zn 0.4% showed significant increased in number of flowers cluster plant^{-1} (27.45), number of flowers cluster^{-1}(5.66), number of fruits cluster^{-1}(4.57), number of branches plant^{-1} (7.36) and yield (t ha^{-1}) (23.40). Based on the above results it can be recommended that Zn @ 0.4% and B @ 0.15% should be combinely applied to tomato for better growth and yield under the agro climatic conditions of Peshawar.

Shnain *et al.* (2014) conducted an experiment with nine treatments with following combination of which was T_1 (control), T_2 (Zn 1.25 g/L), T_3 (Zn 2.0 g/L), T_4 (B 1.25g/L), T_5 (B 1.25g/L + Zn 1.25 g/L), T_6 (B 1.25 g/L), T_7 (B 2.0g/L), T_8 (B 2.0g/L + Zn 1.25g/L) and T_9 (B 2.0 g/L + Zn 2.0 g/L). The cultivar of tomato was "Heem shona" Syngenta Company. The highest fruit weight (72.67 g) was recorded in T_6 and the highest plant height (2.93) m, No. leaves per plant (39.33) leaves, No. clusters per plant (12.33), No. fruits per cluster (7.17), No. fruit per plant (88.33), yield per plant (6.33 kg), total yield (113.628 t /ha) shelf life (26.33 days) Total soluble solid (5.67) Vitamin C (32.57 mg / 100 g) and benefit: cost ratio (4.05 was obtained in T_5 treatment under Allahabad agro climatic conditions.

Kazemi (2013) showed that high Zn (100 mg/L) and Fe (200 mg/L) and their combination significantly promoted vegetative and reproductive growth. Foliar application of Zn (100 mg/L) + Fe (200 mg/L) resulted in the maximum plant height (124.14 cm), branches per plant (8.36), flowers per cluster (18.14), fruits per cluster (8), fruits per plant (90.14), fruit weight (95.14 g), chlorophyll content (22.14 SPAD) and yield (25.14 t ha^{-1}). Fe and Zn alone or in combination had significant effect on leaves-NK content and nitrate reductase activity. The highest TSS (5.87), TA (4 %), pH (2.61 %), fruit firmness (3.66 kg cm^{-2}) and fruit lycopene content (2.25 mg/100 g) were observed when tomato plants treated with 100 mg/L Zn+200 mg/L Fe, thus it was recommended to apply foliar application of Zn and Fe in order to improve growth, flower yield, quality and chemical constituents in tomato plants.

Sivaiah *et al*. (2013) reported that tomato cv. Utkal Kumari, its maximum growth rate (85.7%) was observed with application of zinc, followed by application of micronutrients mixture (78.2%) and boron (77.5%). Tomato cv. Utkal Raja, its branches number per plant increased in maximum which was observed with the application of manganese (148.7%) followed by micronutrient combination (144.1%). In Utkal Kumari, the fruit yield per plant ranged from 1.336 kg to1.867 and in Utkal Raja, it ranged from 1.500 kg to 1.967 kg. In both the varieties, combined application of micronutrients produced the maximum fruit yield followed by application of boron and zinc.

Ejaz *et al.* (2012) investigated that the growth, yield and quality of tomato plant using Zn and N alone and in combination. $ZnSO_4$ was used as a source of Zn (10% and 12%) and urea as source of N (1% and 2%). The results showed that application of either Zn or N alone at both concentrations enhanced growth, yield and quality of tomato plants under poly tunnel. However, the combined use of both Zn and N further enhanced the growth, yield and fruit quality with application of Zn (12%) plus N (2%). Hence the combined use of Zn and N can be a viable strategy for improving yield and quality of tomato.

Gurmani *et al.* (2012) conducted a glasshouse pot experiment to study the effect of soil applied zinc (@ 0, 5, 10 & 15 mg kg^{-1}) on the growth, yield and biochemical attributes in two tomato cultivars; 'VCT-1' and 'Riogrande'. The result showed that zinc application increased the plant growth and fruit yield in both cultivars. Maximum plant growth and fruit yield in both cultivars were achieved by the Zn application at 10 mg kg^{-1} soil. Application of 5 mg Zn kg^{-1} had lower dry matter production as well as fruit yield when compared with Zn 10 and 15 mg kg^{-1}. The percent increase of fruit yield at 5 mg Zn $kg^{-1}$was 14 and 30%, in 'VCT-1' and 'Riogrande', respectively. In the same cultivars, Zn application @ 10 mg Zn kg^{-1} caused the fruit yield by 39 and 54%, while 15 mg Zn kg^{-1}enhanced by 34 and 48%, respectively. Zinc concentration in leaf, fruit and root increased with the increasing level of Zn. Zinc application at 10 and 15 mg kg^{-1}significantly increased chlorophyll, sugar, soluble protein, superoxide dismutase and catalase activity in leaf of both cultivars. The results of the study suggested that soil application of 10 mg Zn kg^{-1} soil have a positive effect on yield, biochemical attributes and enzymatic activities of both the tomato cultivars.

Salama *et al.* (2012) showed that Zn – EDTA at the rate of 0.35 g/pot led to the highest plant height, fresh weight of aerial parts, leaf area, total chlorophyll content, NPK in leaves, fruit setting, and total yield, while the control treatment gave the lowest values for all the previous characters.

Sbartai *et al.* (2011) conducted an experiment to evaluate the response of tomato plants (*Lycopersicon esculentum* L. var. Rio Grande) to treatment with zinc and accumulation (trace element) in the roots and leaves of young plants. This is done by analyzing the effects of zinc on the rate of chlorophyll and enzyme activity involved in the antioxidant system (CAT, GSH, APX). Plants previously grown on a basic nutrient solution is treated by increasing concentrations of $ZnSO_4$ (0, 50, 100, 250, 500 mM) for 07 days. The results showed that Zn does not affect the amount of chlorophyll at 50 and 100 microns, while it seems to inhibit the higher concentrations (250 and 500 microns). On the other hand, treatment with zinc induced the activity of enzymes studied, namely (CAT, APX, GSH) especially for higher concentrations. Finally, the determination of zinc in the roots and leaves of tomato shows a greater accumulation in the roots compared to leaves.

Ejaz *et al.* (2011) found that individual application of nutrient provide better results ascompared to control but their combined effect (Zn = 6%, B = 5%, N = 2%) provided substantial results in plant heights, number of leaves, number of flowers, number of fruits, average fruit weight and yield per plant. It is confirmed from the results that combination of macro-nutrients and micro-nutrients as foliar application has the ability to enhance the growth and yield of tomato positively.

Patil *et al*. (2010) was conducted an experiment to evaluate the effect of foliar application of micronutrients on flowering and fruit-set of tomato. They have showed the flowering parameters like days required for initiation and 50 percent flowering, number of clusters, number of flowers, total number of flowers and fruit setting percentage per plant were influenced significantly due to different treatments. The minimum number of days (30.00) for initiation of flowering and 50% flowering (38.86) were recorded with Boron 50ppm and 100ppm while the maximum number of days were recorded in control. The treatment Boron 100ppm + Iron 200ppm + Zinc 200ppm was most effective in increasing number of clusters (13.85) and number of flowers (51.24) per plant. Maximum number of flowers per cluster and percent fruit setting (47.76%) was recorded with Boron 50ppm + Iron 100ppm+ Zinc 100ppm, while minimum was recorded in control.

Tavassoli *et al*. (2010) performed an experiment to investigate zinc (Zn) and manganese (Mn) nutrition effects on greenhouse tomato in a perlite-containing media. Experimental treatments were: (1) control (Mn and Zn – free nutrition solution), (2) Application of Mn in a concentration equal to the full Hoagland's nutrient solution (4.06 mg/L), (3) application of Zn in a concentration equal to the full Hoagland's nutrient solution (4.42 mg/L), (4) application of Mn and Zn in concentrations equal to the 50% Hoagland's nutrient solution (2.03 mg/L Mn + 2.21 mg/L Zn), and (5) application of Mn and Zn in a concentration equal to the full Hoagland's nutrient solution (4.06 mg/L Mn + 4.42 mg/L Zn). Results showed that the highest fresh-fruit yield and leaf dry matter and content of Mn and Zn in fruit were obtained from single or combined application of Mn and Zn in concentrations equal to the full Hoagland's nutrient solution. In addition, Zn and Mn nutrition significantly affected the fruit concentrations of crude protein, nitrogen and phosphorus, while the effect of these treatments on fruit size of tomato was not significant.

Salam *et al.* (2010) reported that the highest pulp weight (88.14%), dry matter content (5.34%), TSS (4.50%), acidity (0.47%), ascorbic acid (10.95 mg/100g), lycopene content (112.00 μg/100g), chlorophyll-a (41.00μg/100g), chlorophyll-b (56.00 μg/100g), marketable fruits at 30 days after storage (67.48%) and shelf life (16 days) were recorded with the combination of 2.5 kg B+ 6 kg Zn/ha and recommended dose of NPK fertilizers (N= 253, P= 90, and K= 125 kg/ha).

Raghav and Sharma (2003) reported in tomato, okra and pea cropping sequence, a basal application of 40 kg $ZnSO_4$ ha^{-1}. A foliar spray of 2.5 to 5.0 kg $ZnSO_4$ ha^{-1} once at 25 DAT and twice at 25 and 40 DAT recorded highest yield of 215.0, 5.0 and 46.2 q ha^{-1} in tomato, okra and pea respectively.

Dube *et al.* (2003) obtained quality of tomato fruits containing highest tritratable acidity 0.82 percent when Zn applied to soil 5.0 mg/kg, which is closely followed by application 10 mg of Zn per kg of soil (0.70%) while it was (0.34%) in control. reported highest lycopene (4.30 mg) for 100 g of fruit by soil application of zinc at the rate of 5 mg kg^{-1} of soil which is closely followed by soil application at the rate of 10 mg kg^{-1} soil obtained the lycopene content (3.40 mg) compared to the control (0.40 mg 100 $g^{-1}$of fruits).

Yadav *et al.* (2001) studied with tomato and reported that the highest value of secondary branches, leaf area, and total chlorophyll content, fresh weight, fruit length, fruit girth, fruit number and highest yield were obtained with the application of 7.5 ppm zinc and 1.0 ppm boron as soil application, as well as foliar application of 0.5% zinc and 0.3% boron.

Makhan *et al*. (2000) was conducted a field experiment for the response of foliar application of micronutrients on tomato variety at Vegetable Research Farm and Laboratory of CCS Haryana Agricultural University. The treatments were ammonium molybdate, borax, copper sulphate, ferrous sulphate, manganese sulphate, zinc sulphate, mixture of all micronutrients and control. The micronutrients were applied as foliar spray @5 g per liter (0.5%) at the interval of ten days i.e. 40, 50, 60 days after transplanting. Mixture was made by taking all the micronutrients in equal proportion i.e. 0.83 g and mixed thoroughly. The result indicates that application of all the micronutrients, significantly enhanced plant height over control. The highest increase in plant height (54.80 cm) was recorded with application of Zinc sulphate. They have concluded that Zinc may serve as source of energy for synthesis of auxin which helps in elongation of stem.

Cakmak *et al.* (1999) reported that zinc also helps in various metabolic processes; its deficiency inhibits growth and development of plants.

Hussain *et al*. (1989) recorded more number of seeds in foliar spray of zinc, boron and iron combined each at 0.1% and 100 seeds weighs 0.57 g which is closely followed by foliar spray of zinc at 0.1% recorded 100 seeds weight of 0.56 g compared to control (0.55 g).

Chapter III

Materials & Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from October, 2015 to March, 2016 to study the effect of different levels of nitrogen and zinc on growth and yield of tomato. This chapter includes materials and methods that were used in conducting the experiment and presented below under the following headings:

3.1 Location of the experimental field

The experiment was conducted at Horticulture farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from October, 2015 to March, 2016. The location of the experimental site was at 23^0 $46^/$N latitude and $90^0 22^/$E longitudes with an elevation of 8.24 meter from sea level.

3.2 Climate of the experimental area

The experimental area is characterized by sub-tropical rainfall during the month of May to September and scattered rainfall during the rest of the year. Information regarding 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 of the experimental field

Soil of the study site was silty clay loam in texture belonging to Tejgaon series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 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 Plant materials collection

The tomato variety used in the experiment was "BARI Tomato-2 (Ratan)". This is a high yielding indeterminate type variety. The seeds were collected from Olericulture division of Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.5 Raising of seedlings

Tomato seedlings were raised in two seedbeds on a relatively high land at Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka. The size of each seedbed was 2 m × 1m. The soil was well prepared and converted into loose friable and dried mass by spading. All weeds and stubbles were removed and 5 kg well rotten cowdung was mixed with the soil. The seeds were sown in the seedbed on 25 October, 2015 and after sowing, seeds were covered with light soil. The emergence of the seedlings took place within 6 to 7 days after sowing. Necessary shading by banana leaves was provided over the seedbed to protect the young seedlings from scorching sun or heavy rain. Weeding, mulching and irrigation were done as and when required and no chemical fertilizer was used in the seedbed.

3.6 Treatments of the experiment

The experiment consisted of two factors as follows:

Factor A: Four levels of Nitrogen

N_0 = Control

N_1 = 100 kg nitrogen ha^{-1}

N_2 = 120 kg nitrogen ha^{-1}

N_3 = 140 kg nitrogen ha^{-1}

Factor B: Three levels of Zinc

Zn_0 = Control

Zn_1 = 1 kg zinc ha^{-1}

Zn_2 = 2 kg zinc ha^{-1}

There were altogether 12 (4×3) treatments combination used in each block.

N_0Zn_0, N_0Zn_1, N_0Zn_2, N_1Zn_0, N_1Zn_1, N_1Zn_2, N_2Zn_0, N_2Zn_1, N_2Zn_2, N_3Zn_0, N_3Zn, N_3Zn_2

3.7 Design and layout of the experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) having two factors with three replications. An area of 29.1 m × 10 m was divided into three equal blocks. Each block was consists of 12 plots where 12 treatments were allotted randomly. There were 36 unit plots in the experiment. The size of each plot was 2 m × 1.8 m. The distance between two blocks and two plots were kept 1 m and 0.5 m respectively. A layout of the experiment has been shown in figure 1.

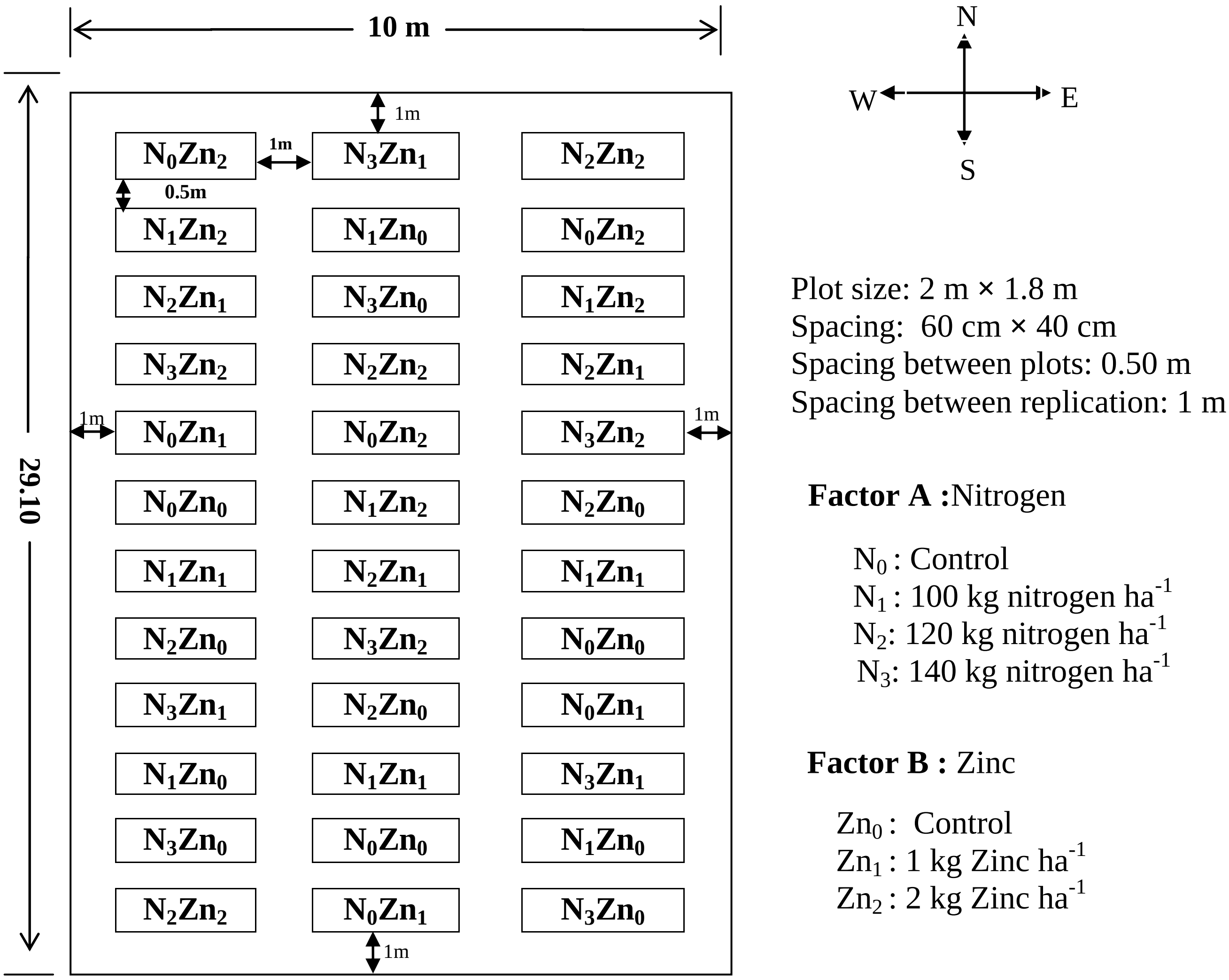

Fig 1: Field layout of the experimental plot

3.8 Cultivation procedure

3.8.1 Land preparation

The soil was well prepared and good tilth was ensured for commercial crop production. The land of the experimental field was ploughed with a power tiller on November 2015. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and then the land was made ready. The field layout and design was followed after land preparation.

3.8.2 Manures and fertilizers

Fertilizer	Quantity	Application method
Cowdung	15 t/ha	Basal dose
Urea	As per treatment	20, 30 and 40 DAT
TSP	300 kg/ha	Basal dose
MoP	250 kg/ha	20, 30 and 40 DAT mixed with urea
Zinc Sulphate	As per treatment	Final land preparation

Rashid (2012).

According to Rashid (2012), the entire amount of cowdung, TSP as a source of phosphorus and zinc sulphate heptahydrate ($ZnSO_4.7H_2O$) as a source of zinc were applied as basal dose during final land preparation. Urea and MoP as a source of nitrogen and potassium were applied as per treatment and 250 kg/ha respectively in three equal splits at 20, 30 and 40 days after transplanting as ring method.

3.8.3 Transplanting of seedlings

Healthy and uniform 30 days old seedlings were uprooted separately from the seed bed and were transplanted in the experimental plots in 26th November, 2015 maintaining a spacing of 60 cm x 40 cm between the rows and plants, respectively. This allowed an accommodation of 15 plants in each plot. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage to the roots. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.8.4 Intercultural operations

After seedlings transplanting, various intercultural operations such as irrigation, weeding, staking and top dressing etc. were accomplished for better growth and development and quality of the tomato seedlings.

3.8.4.1 Gap filling

When the seedlings were well established, the soil around the base of each seedling was pulverized. A few gaps filling was done by healthy seedlings of the same stock where initial planted seedling failed to survive.

3.8.4.2 Weeding

Numbers of weeding were accomplished as and whenever necessary to keep the crop free from weeds.

3.8.4.3 Staking

When the plants were well established, staking was given to each plant by rope and plastic wire to keep them erect. Within a few days of staking, as the plants grew up, other cultural operations were carried out.

3.8.4.4 Irrigation

Number of irrigation was given throughout the growing period by garden pipe and watering cane. The first irrigation was given immediate after the transplantation where as others were applied when and where required depending upon the condition of soil.

3.8.4.5 Plant protection

From seedling to harvesting stage i.e. any stage, tomato is very sensitive to diseases and pest. After getting a maturity stage protection measure was taken against diseases and pests. So that, any insect or fungal infection and insect infestation cannot appear in the plant.

3.8.4.6 Insect pests

Bavistin 50 WP and Ripcord 10 EC were applied @ 10 ml/L against the fungal diseases, leaf curl disease and insect pests like cut worm, leaf hopper, fruit borer and others. The insecticide application was made fortnightly for a week after transplanting to two weeks before first harvesting.

3.9 Harvesting

Fruits were harvested at 7 to 8 days intervals during early ripe stage when they attained slightly red color. Harvesting was started from 1 March, 2016 and was continued up to end of 22 March, 2016.

3.10 Data collection

Six plants were selected randomly from each plot for data collection in such a way that the border effect could be avoided for the highest precision. Data on the following parameters were recorded from the sample plants during the course of experiment.

3.10.1 Plant height

The plant height was measured from the base of plant to the terminal growth point of main stem on tagged plants which was recorded at 10 days interval starting from 20 days of planting up to 60 days to observe the plant height. The average height was computed and expressed in centimeter.

3.10.2 Number of leaves plant^{-1}

The number of leaves per plant was manually counted at 20, 30, 40, 50 and 60 days after transplanting from randomly selected tagged plants. The average of six plants were computed and expressed in average number of leaves per plant.

3.10.3 Number of branches plant^{-1}

The number of branches per plant was manually counted at 20, 30, 40, 50 and 60 days after transplanting from randomly selected tagged plants. The average of six plants were computed and expressed in average number of branch per plant.

3.10.4 Canopy size

The canopy size of the plant was manually recorded at 20, 30, 40, 50 and 60 days after transplanting from randomly selected tagged plants. The average of six plants were computed and expressed in average canopy size of the plant.

3.10.5 Stem diameter

The stem diameter of the plant was manually measured by slide calipers at 20, 30, 40, 50 and 60 days after transplanting from tagged plants. The average of six plants were measured and expressed in average stem diameter of the plant.

3.10.6 Number of cluster plant^{-1}

The number of flower clusters was counted at 50 and 60 days after transplanting from the 6 sample plants and the average number of clusters produced per plant was recorded.

3.10.7 Number of flowers cluster^{-1}

The number of flowers per cluster was counted at 50 and 60 days after transplanting from the 6 sample plants. From each plant randomly five clusters were selected and counted the number of flowers per cluster to make an average value for one plant. The final average value of number of flowers per cluster was calculated.

3.10.8 Number of fruits cluster^{-1}

The number of fruits per cluster was counted at 60 DAT and harvesting time from selected 6 plants. From each plant randomly five clusters were selected and counted the number of fruits per cluster to make an average value for one plant. The final average value of number of fruits per cluster was calculated from 6 averages from six plants.

3.10.9 Length of fruit

Among the total number of fruit harvested during the period from first to final harvest, the fruits, except the first and last harvest, were considered for determine the length of fruit by slide calipers. The length of fruit was calculated by making the average of five fruits from each of the six plants.

3.10.10 Diameter of fruit

Among the total number of fruits harvested during the period from first to final harvest, the fruits, except the first and last harvest, were considered for determine the diameter of fruit by slide calipers. The diameter of fruit was calculated by making the average of five fruits from each of the six plants.

3.10.11 Fresh weight of fruit

Among the total number of fruit harvested during the period from first to final harvest, the fruits, except the first and last harvest, were considered for determine the individual fruit weight in gram. The weight was calculated from total weight of fruits was divided by total number of fruits of every harvest and finally making the average was made from four times harvesting data.

3.10.12 Dry matter content of fruit

After harvesting, randomly selected 100 gram of fruit sample previously sliced in to very thin pieces. The fruits were then dried in the sun for one day and placed in oven maintained temperature at 60^0C for 72 hrs. The sample was then transferred into desiccators and allowed to cool down to the room temperature. The final weight of the sample was taken. The dry matter was calculation by the following formula:

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

3.10.13 Chlorophyll content in leaf

The Chlorophyll percentage of leaf of the plant was measured by a SPAD meter, a product of Konica Minolta Sensing Ltd, Singapore, at 60 days after transplanting from randomly selected six tagged plants. This machine gives the direct calculated value of the chlorophyll percentage of leaf of the plant. The Chlorophyll percentage of five tagged leaves of each plant was measured and calculated the average Chlorophyll percentage of leaf of each plant of 6 sample plants.

3.10.14 TSS (Total Soluble Solid)

Brix refractometer (Model RHB 32 ATC) was used to measure TSS. One tomato sample was collected from each of the treatment. Tomato sample was cut with the sharp knife and inside was squeeze with the needle for sample juice. A drop of juice was placed on the transparent glass and it was covered by the upper glass. Brix refractometer was directly showed the TSS as percentage.

3.10.15 Vitamin C content

Preparation of Dye solution:

Dye = 260 mg

$NaHCO_3$= 21 mg

Distilled water= 1L= 1000 mL

Here,Known sample of ascorbic acid= 10 mg % of ascorbic acid

Meta phosphoric acid= 3%

Titration value of known sample = 5.3

Procedure:

At first 5 gm fruit with 50 ml meta phosphoric acid was blending well in a Blender. Then it was filtered in a 100 ml volumetric flask and was maken it 100 mL with meta phosphoric acid. Then it was taken 5 ml solution in 250 ml volumetric flask and was titrated with dye solution. Then titration value of each treatment was recorded and was calculated by the following formula:

$$\text{Ascorbic acid (mg/100g)} = \frac{T \times D \times V_1}{V_2 \times W} \times 100$$

Where,

T = Titrate value

D = Dye factor = $\frac{0.5}{\text{Titrate}}$

V_1= Volume to be made (ml)

V_2= Volume of extract taken for titration (ml)

W = Weight of sample taken for estimation (g)

3.10.16 Yield plant^{-1}

Yield of tomato per plant was recorded as the whole fruit per plant and was expressed in kilogram (kg).It was measured by the following formula:

$$\text{Weight of fruits per plant (Kg)} = \frac{\text{Total weight of fruits in 10 sample plants}}{10}$$

3.10.17 Yield plot^{-1}

An electric balance was used to measure the weight of fruits per plot. The total fruit yield of each unit plot measured separately from each sample plant during the harvesting period and was expressed in kilogram (kg).

3.10.18 Yield (per hectare)

It was measured by the following formula:

$$\text{Yield of tomato (t/ha)} = \frac{\text{Fruit yield per unit plot (kg) x 10000 kg}}{\text{Area of unit plot in square meter x 1000 kg}}$$

3.11 Statistical analysis

The data obtained for different characters were statistically analyzed using MSTAT-C software to find out the significance of the difference. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the means of treatment combinations was estimated by LSD at 5% level of probability (Gomez and Gomez, 1984).

Chapter IV

Results and Discussion

CHAPTER IV

RESULT AND DISCUSSION

The present study was conducted to find out the effect of nitrogen and zinc on growth and yield of tomato. Data on different growth and yield contributing characters were recorded. The analysis of variance (ANOVA) of the data on different growth and yield parameters are given in Appendix III-IX. The results have been presented and discussed with the help of tables and graphs and possible interpretations were given under the following headings:

4.1 Plant height

In case of nitrogen application significant difference was observed at 30, 40, 50 and 60 DAT except 20 DAT (Appendix III). At 20, 30, 40, 50 and 60 DAT the maximum plant height (14.77 cm, 25.22 cm, 55.00 cm, 68.11 cm and 80.88 cm) was obtained from N_2 (120 kg nitrogen ha^{-1}) treatment. On the other hand, at 20, 30, 40, 50 and 60 DAT minimum plant height (12.77 cm, 21.66 cm, 47.66 cm, 58.77 cm and 68.55 cm) was recorded from N_0 (Control) treatment (Figure 2). Singh and Sharma (1999) stated that, plant height, number of leaves increased with N levels. Sandoval *et al.* (1999) supported the results.

The significant difference was observed due to the application of zinc at 30, 40, 50 and 60 DAT except 20 DAT (Appendix III). At 20 and 30 DAT the maximum plant height (16.16 cm and 28.50 cm) was obtained from Zn_1 (1 kg zinc ha^{-1}) treatment and at 40, 50 and 60 DAT the highest plant height (59.33 cm, 74.33 cm and 90.50 cm) was recorded from Zn_2 (2 kg zinc ha^{-1}) treatment. On the other hand, at 20, 30, 40, 50 and 60 DAT minimum plant height (11.58 cm, 19.33 cm, 43.16 cm, 53.58 cm and 60.91cm) was recorded from Zn_0 (Control) treatment (Figure 3). Makhan *et al*. (1999-2000) found that highest increase in plant height (54.80 cm) was recorded with the application of zinc sulphate. They have concluded that zinc may serve as source of energy for synthesis of auxin which helps in elongation of stem. Ali *et al.* (2015) conducted an experiment to increase the yield of BARI hybrid tomato 4, cultivated in summer season of Bangladesh with foliar application of zinc which supported the similar results.

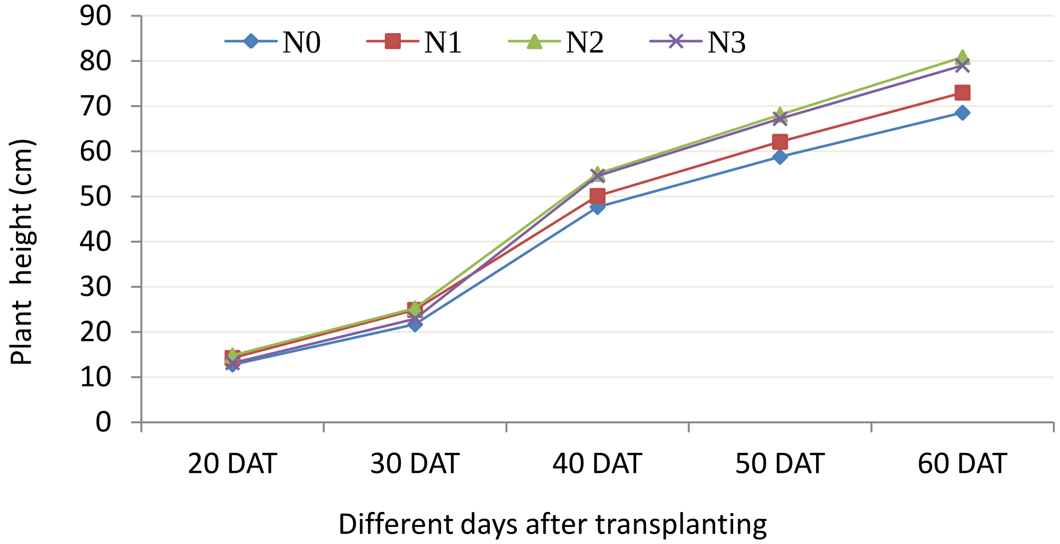

Figure 2. Effect of nitrogen on plant height of tomato

N_0: Control, N_1: 100 kg nitrogen ha^{-1}, N_2: 120 kg nitrogen ha^{-1}, N_3: 140 kg nitrogen ha^{-1}

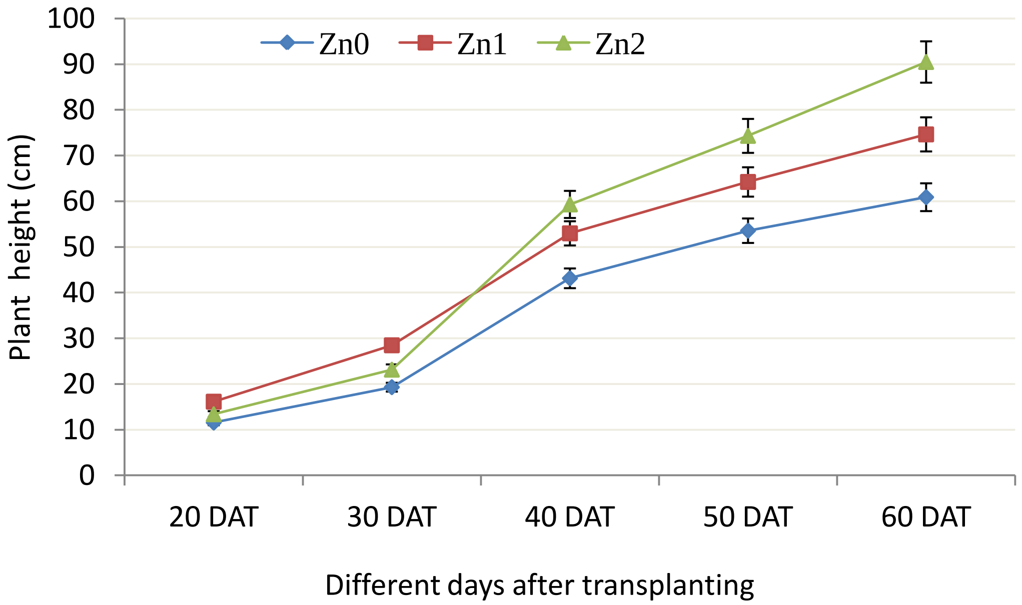

Figure 3. Effect of zinc on plant height of tomato

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

Table 1. Combined effect of nitrogen and zinc on plant height of tomato

Treatment	Plant Height (cm)				
	20 DAT	**30 DAT**	**40 DAT**	**50 DAT**	**60 DAT**
N_0Zn_0	11.00 f	17.33 g	36.00 f	48.00 g	53.00 g
N_0Zn_1	12.66 de	21.00 ef	50.00 de	58.66 ef	67.66 ef
N_0Zn_2	14.66 c	26.66 bc	57.00 b	69.66 bc	85.00 bc
N_1Zn_0	11.33 f	19.33 fg	41.33 f	53.00 fg	61.00 fg
N_1Zn_1	13.00 de	22.00 e	51.33 cde	61.66 de	70.66 de
N_1Zn_2	15.00 bc	27.33 bc	57.66 ab	71.66 bc	87.33 bc
N_2Zn_0	12.00 ef	20.00 ef	47.33 e	56.66 ef	64.33 ef
N_2Zn_1	13.33 d	24.33 d	54.66 bcd	67.66 cd	79.33 cd
N_2Zn_2	16.00 b	28.66 b	63.00 a	80.00 a	99.00 a
N_3Zn_0	12.00 ef	20.66 ef	48.00 e	56.66 ef	65.33 ef
N_3Zn_1	14.66 c	25.33 cd	56.00 bc	69.00 bc	81.00 c
N_3Zn_2	19.00 a	31.33 a	59.66 ab	76.00 ab	90.66 ab
$LSD_{(0.05)}$	1.08	2.13	5.54	7.27	9.26
CV %	4.69	5.32	6.32	6.70	7.26

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

N_0: Control
N_1: 100 kg nitrogen ha^{-1}
N_2: 120 kg nitrogen ha^{-1}
N_3: 140 kg nitrogen ha^{-1}

Zn_0: Control
Zn_1: 1 kg zinc ha^{-1}
Zn_2: 2 kg zinc ha^{-1}

The significant difference was observed due to the combined effect of different levels of nitrogen and zinc application at 30, 40, 50 and 60 DAT except 20 DAT (Appendix III). At 20 and 30 DAT the maximum plant height (19.00 cm and 31.33 cm) was obtained from N_3Zn_2 (140 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1}) treatment combination and at 40, 50 and 60 DAT, the highest plant height (63.00 cm, 80.00 cm and 99.00 cm) was recorded from N_2Zn_2 (120 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1}) treatment combination. On the other hand, at 20, 30, 40, 50 and 60 DAT minimum plant height (11.00 cm, 17.33 cm, 36.00 cm, 48.00 cm and 53.00 cm) was recorded from N_0Zn_0 (Control) treatment combination (Table 1). Kishan *et al.* (1997) also found similar results. Grela *et al.* (1988) reported that nitrogen was applied to tomato cultivars and plant height was increased.

4.2 Number of leaves plant^{-1}

Due to different levels of nitrogen application significant difference was observed at 30, 40, 50 and 60 DAT except 20 DAT (Appendix IV). At 20 and 30 DAT maximum number of leaves plant^{-1} (5.88 and 10.00) was obtained from N_2 (120 kg nitrogen ha^{-1}) treatment and at 40, 50 and 60 DAT the maximum number of leaves plant^{-1} (36.66, 51.22 and 73.22) was obtained from N_2 (120 kg nitrogen ha^{-1}) treatment. On the other hand, at 20, 30, 40, 50 and 60 DAT minimum number of leaves plant^{-1} (5.66, 7.55, 26.77, 39.55 and 59.11) was recorded from N_0 (control) treatment (Figure 4). Singh and Sharma (1999) stated that, number of leaves increased with N levels.

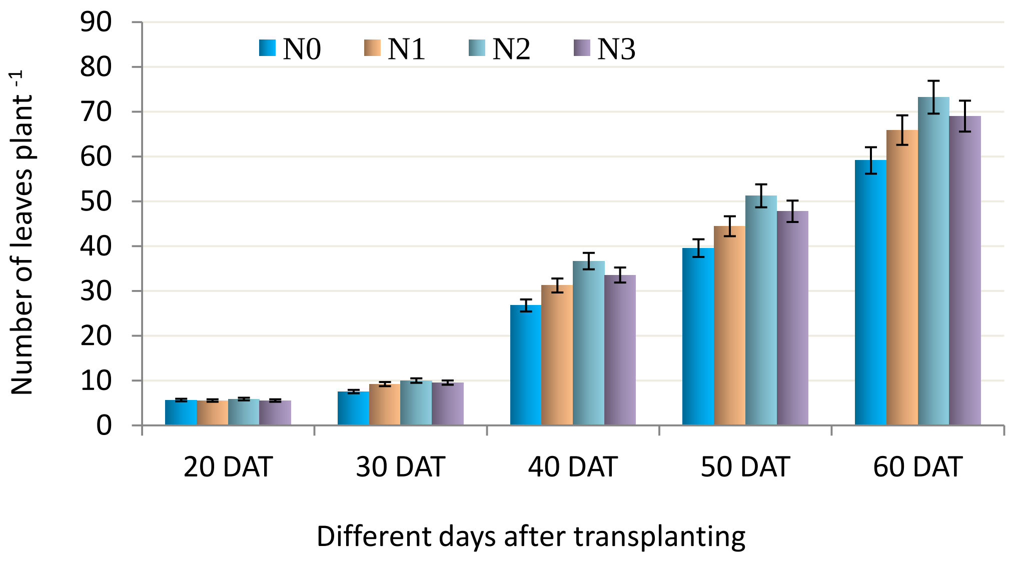

Figure 4. Effect of nitrogen on number of leaves plant^{-1} of tomato

N_0: Control, N_1: 100 kg nitrogen ha^{-1}, N_2: 120 kg nitrogen ha^{-1}, N_3: 140 kg nitrogen ha^{-1}

In case of different levels of zinc application significant difference was observed at 30, 40, 50 and 60 DAT except 20 DAT (Appendix IV). At 20 and 30 DAT the maximum number of leaves plant^{-1} (5.91 and 10.58) was obtained from Zn_1 (1 kg zinc ha^{-1}) treatment and at 40, 50 and 60 DAT, the highest number of leaves plant^{-1}(37.91, 53.91 and 76.16) was recorded from Zn_2 (2 kg zinc ha^{-1}) treatment. On the other hand, at 20, 30, 40, 50 and 60 DAT minimum number of leaves plant^{-1} (5.33, 8.41, 27.83, 40.25 and 60.25) was recorded from Zn_0 (Control) treatment (Figure 5). Ejaz *et al.* (2011) found that individual application of nutrient provide better results as compared to control but their combined effect provided substantial results in plant heights, number of leaves of the plant. Cakmak *et al.* (1999) reported that zinc also helps in various metabolic processes; its deficiency inhibits growth and development of plants.

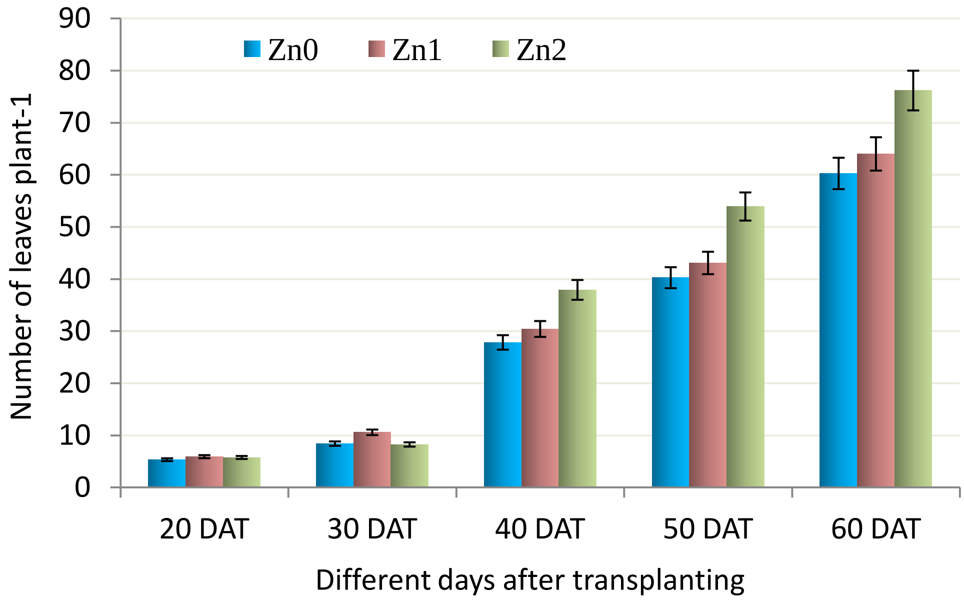

Figure 5. Effect of zinc on number of leaves plant^{-1} of tomato

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

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

Treatment	Number of leaves plant^{-1}				
	20 DAT	**30 DAT**	**40 DAT**	**50 DAT**	**60 DAT**
N_0Zn_0	5.33 ab	7.33 f	22.00 f	33.33 e	50.66 e
N_0Zn_1	5.66 ab	8.00 ef	29.00 de	43.00 d	64.00 d
N_0Zn_2	6.00 a	7.33 f	29.33 de	42.33 d	62.66 d
N_1Zn_0	5.33 ab	9.33 cd	30.33 cde	42.00 d	63.33 d
N_1Zn_1	5.66 ab	8.00 ef	27.00 ef	39.00 de	59.00 de
N_1Zn_2	5.66 ab	10.33 c	36.33 bc	52.33 bc	75.33 bc
N_2Zn_0	5.66 ab	8.66 de	30.00 cde	44.00 d	65.00 d
N_2Zn_1	6.00 a	8.33 def	34.33 bcd	45.33 cd	66.00 d
N_2Zn_2	6.00 a	11.66 b	45.66 a	64.33 a	88.66 a
N_3Zn_0	5.00 b	8.33 def	29.00 de	41.66 d	62.00 d
N_3Zn_1	5.66 ab	8.66 de	31.33 cde	45.00 d	67.00 cd
N_3Zn_2	6.00 a	13.00 a	40.33 ab	56.66 b	78.00 b
LSD $_{(0.05)}$	0.93	1.29	6.36	7.05	8.68
CV %	9.71	8.41	11.73	9.10	7.68

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

N_0: Control
N_1: 100 kg nitrogen ha^{-1}
N_2: 120 kg nitrogen ha^{-1}
N_3: 140 kg nitrogen ha^{-1}

Zn_0: Control
Zn_1: 1 kg zinc ha^{-1}
Zn_2: 2 kg zinc ha^{-1}

From the combined effect of different levels of nitrogen and zinc application significant difference was observed at 30, 40, 50 and 60 DAT except 20 DAT (Appendix IV). At 20 and 30 DAT the maximum number of leaves plant^{-1} (6.00 and 13.00) was obtained from N_3Zn_2 treatment combination and at 40, 50 and 60 DAT, the highest number of leaves plant^{-1} (45.66, 64.33 and 88.66) was recorded from N_2Zn_2 (120 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1}) treatment combination. On the other hand at 20 DAT , 30, 40, 50 and 60 DAT minimum number of leaves plant^{-1} (5.00, 7.33, 22.00, 33.00 and 50.66) was recorded from N_0Zn_0 (Control) treatment combination (Table 2).

4.3 Number of branches plant^{-1}

By different levels of nitrogen application significant difference was found (Appendix V). The maximum number of branches plant^{-1} (6.88) was obtained from N_2 (120 kg nitrogen ha^{-1}) treatment and followed by (6.48) N_1 treatment which is statistically identical to N_3 treatment. On the other hand the minimum number of branches plant^{-1} (4.70) was recorded from N_0 (Control) treatment (Table 3). Adjanohoun *et al.* (1996) conducted a field trial and found the similar results.

The significant difference was observed due to the application of different levels of zinc (Appendix V). The maximum number of branches plant^{-1} (6.82) was obtained from Zn_2 (2 kg zinc ha^{-1}) treatment and followed by (6.12) Zn_1 treatment. On the other hand, the minimum number of branches plant^{-1} (5.42) was recorded from Zn_0 (Control) treatment (Table 4). Ullah *et al.* (2015) found significant increase in number of branches plant^{-1} and yield with different levels of Zn.

The significant difference was observed due to the combined effect of different levels of nitrogen and zinc application (Appendix V). The maximum number of branches plant^{-1} (7.77) was obtained from N_2Zn_2 (120 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1}) treatment combination. On the other hand, the minimum number of branches plant^{-1} (3.77) was recorded from N_0Zn_0 (Control) treatment combination (Table 5).

4.4 Canopy size

The significant difference was found in case of different levels of nitrogen application (Appendix V). The maximum canopy size (79.54 cm) was obtained from N_2 (120 kg nitrogen ha^{-1}) treatment followed by (76.15 cm) at N_3 treatment. On the other hand the minimum canopy size (62.23) was recorded from N_0 (Control) treatment (Table 3). Adjanohoun *et al.* (1996) conducted a field trial and found the similar results.

Due to different levels of zinc application significant differences was found (Appendix V). The maximum canopy size (81.31 cm) was obtained from Zn_2 (2 kg zinc ha^{-1}) treatment and followed by (71.23 cm) Zn_1 treatment. On the other hand, the minimum canopy size (60.52 cm) was recorded from Zn_0 (Control) treatment (Table 4). Ejaz *et al.* (2011) found that individual application of nutrient provide better results as compared to control but their combined effect provided substantial results in canopy size.

The significant difference was also observed due to the combined effect of different nitrogen and zinc application (Appendix V). The maximum canopy size (92.00 cm) was obtained from N_2Zn_2 (120 kg nitrogen $ha^{-1}$and 2 kg zinc ha^{-1}) treatment combination. On the other hand, the minimum canopy size (58.00 cm) was recorded from N_0Zn_0 (Control) treatment combination (Table 5). Staneve (1983) conducted an experiment to investigate the effect of nitrogen supply on photosynthesis, leaf area and total dry matter in tomato which was inhabited by N deficiency.

Table 3. Effect of nitrogen on number of branches plant^{-1}, canopy size and stem diameter of tomato

Treatment	Number of branches plant^{-1}	Canopy size (cm)	Stem diameter (cm)
N_0	4.70 c	62.23 d	1.98 d
N_1	6.48 b	70.12 c	2.32 b
N_2	6.88 a	79.54 a	2.40 a
N_3	6.41 b	76.15 b	2.28 c
LSD $_{(0.05)}$	0.08	1.22	0.015
CV %	7.15	6.12	5.23

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

N_0: Control, N_1: 100 kg nitrogen ha^{-1}, N_2: 120 kg nitrogen ha^{-1}, N_3: 140 kg nitrogen ha^{-1}

Table 4. Effect of zinc on number of branches plant^{-1}, canopy size and stem diameter of tomato

Treatment	Number of branches plant^{-1}	Canopy size (cm)	Stem diameter (cm)
Zn_0	5.42 c	60.52 c	2.11 c
Zn_1	6.12 b	71.23 b	2.23 b
Zn_2	6.82 a	81.31 a	2.40 a
LSD $_{(0.05)}$	0.07	2.12	0.013
CV %	7.15	6.12	5.23

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 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}

4.5 Stem diameter

In case of nitrogen application significant difference was found (Appendix V). The maximum stem diameter (2.40 cm) was obtained from N_2 (120 kg nitrogen ha^{-1}) treatment followed by (2.32 cm) N_1 treatment. On the other hand the minimum stem diameter (1.98 cm) was recorded from N_0 (Control) treatment (Table 3). Adjanohoun *et al.* (1996) conducted a field trial and supported the similar results

The significant difference was observed due to the application of zinc (Appendix V). The maximum stem diameter (2.40 cm) was obtained from Zn_2 (2 kg zinc ha^{-1}) treatment and followed by (2.23 cm) Zn_1 treatment. On the other hand, the minimum stem diameter (2.11 cm) was recorded from Zn_0 (control) treatment (Table 4). Shnain *et al.* (2014) supported the results.

Due to the combined effect of different levels of nitrogen and zinc application significant difference was observed (Appendix V). The maximum stem diameter (2.61 cm) was obtained from N_2Zn_2 (120 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1}) treatment combination. On the other hand, the minimum stem diameter (1.86 cm) was recorded from N_0Zn_0 (Control) treatment combination (Table 5).

Table 5. Combined effect of nitrogen and zinc on number of branches plant^{-1}, canopy size and stem diameter of tomato

Treatment	Number of branches plant^{-1}	Canopy size (cm)	Stem diameter (cm)
N_0Zn_0	3.77 j	58.00 i	1.86 j
N_0Zn_1	4.77 i	73.33 f	1.98 i
N_0Zn_2	5.57 h	79.00 d	2.11 h
N_1Zn_0	5.90 g	62.00 h	2.19 g
N_1Zn_1	6.57 d	75.00 e	2.30 d
N_1Zn_2	6.97 b	82.00 c	2.48 b
N_2Zn_0	6.10 f	72.00 g	2.22 f
N_2Zn_1	6.77 c	76.00 e	2.39 c
N_2Zn_2	7.77 a	92.00 a	2.61 a
N_3Zn_0	5.90 g	71.67 g	2.18 g
N_3Zn_1	6.37 e	76.00 e	2.26 e
N_3Zn_2	6.97 b	86.00 b	2.41 c
LSD $_{(0.05)}$	0.14	1.10	0.026
CV %	7.15	6.12	5.23

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

N_0: Control
N_1: 100 kg nitrogen ha^{-1}
N_2: 120 kg nitrogen ha^{-1}
N_3: 140 kg nitrogen ha^{-1}

Zn_0: Control
Zn_1: 1 kg zinc ha^{-1}
Zn_2: 2 kg zinc ha^{-1}

4.6 Number of clusters plant^{-1}

From different levels of nitrogen application significant difference was found (Appendix VI). The maximum number of clusters plant^{-1} (10.93) was obtained from N_2 (120 kg nitrogen ha^{-1}) treatment and followed by (9.15) N_1 treatment. On the other hand the minimum number of clusters plant^{-1} (5.26) was recorded from N_0 (Control) treatment (Table 6). Singh and Sharma (1999) stated that, number of cluster, fruit weight and yield increased with increasing N level.

The significant difference was found due to the application of different levels of zinc (Appendix VI). The maximum number of clusters plant^{-1} (10.93) was obtained from Zn_2 (2 kg zinc ha^{-1}) treatment and followed by (8.43) Zn_1 treatment. On the other hand, the minimum number of clusters plant^{-1}(6.18) was recorded from Zn_0 (control) treatment (Table 7). Ullah *et al.* (2015) found significant increase in number of flowers cluster plant^{-1}, number of flowers cluster^{-1}, number of fruits cluster^{-1}, number of branches plant^{-1}and yield ha^{-1}.

Due to the combined effect of different levels nitrogen and zinc application significant difference was observed (Appendix VI). The maximum number of clusters plant^{-1} (14.93) was obtained from N_2Zn_2 (120 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1}) treatment combination. On the other hand, the minimum number of clusters plant^{-1} (4.93) was recorded from N_0Zn_0 (control) treatment combination (Table 8). Huett (1993) with tomato cv. Flora-Dade on krasnozem soils to examine the effects of N and agreed with the results.

4.7 Number of flowers cluster^{-1}

Due to different levels of nitrogen application significant difference was found (Appendix VI). The maximum number of flowers cluster^{-1} (6.72 was obtained from N_2 (120 kg nitrogen ha^{-1}) treatment and followed by (6.39) N_1 treatment. On the other hand the minimum number of flowers cluster^{-1} (4.79) was found from N_0 (Control) treatment (Table 6). Singh and Sharma (1999) stated that, percentage flower and fruit set, fruit weight and yield increased with increasing N level.

The significant difference was observed due to the application of different levels of zinc (Appendix VI). The maximum number of flowers cluster^{-1} (6.57) was found from Zn_2 (2 kg zinc ha^{-1}) treatment and followed by (6.05) Zn_1 treatment. On the other hand, the minimum number of flowers cluster^{-1} (5.47) was recorded from Zn_0 (Control) treatment (Table 7). Ullah *et al.* (2015) also found significant increase in number of flowers cluster^{-1} by the application of Zn.

By the combined effect of different levels nitrogen and zinc application significant difference was found (Appendix VI). The maximum number of flowers cluster^{-1} (7.52) was obtained from N_2Zn_2 (120 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1}) treatment combination. On the other hand, the minimum number of flowers cluster^{-1} (4.52) was recorded from N_0Zn_0 (Control) treatment combination (Table 8).

4.8 Number of fruits cluster^{-1}

Due to the individual application of different levels of nitrogen significant difference was found (Appendix VI). The maximum number of fruits cluster^{-1} (6.48) was obtained from N_2 (120 kg nitrogen ha^{-1}) treatment and followed by (5.70) N_3 treatment which is statistically identical to (5.59) N_1 treatment. On the other hand the minimum number of fruits cluster^{-1}(2.93) was found from N_0 (Control) treatment (Table 6). Singh and Sharma (1999) stated that, plant height, number of leaves, percentage fruit set, fruit weight and yield increased with increasing N level.

The significant difference was found due to the application of different levels of zinc (Appendix VI). The maximum number of fruits cluster^{-1} (6.18) was found from Zn_2 (2 kg zinc ha^{-1}) treatment and followed by (5.43) Zn_1 treatment. On the other hand, the minimum number of fruits cluster^{-1} (3.93) was recorded from Zn_0 (Control) treatment (Table 7). Ullah *et al.* (2015) found significant increase in number of flowers cluster plant^{-1}, number of flowers cluster^{-1}, number of fruits cluster^{-1}. Sivaiah *et al.* (2013) found combined application of micronutrients produced the maximum fruit yield followed by application of boron and zinc.

In case of combined application of different levels of nitrogen and zinc application significant difference was observed (Appendix VI). The maximum number of fruits cluster^{-1} (7.93) was obtained from N_2Zn_2 (120 kg nitrogen ha^{-1}

and 2 kg zinc ha^{-1}) treatment combination. On the other hand, the minimum number of fruits cluster^{-1} (2.93) was recorded from N_0Zn_0 (Control) treatment combination (Table 8).

Table 6. Effect of nitrogen on number of clusters plant^{-1}, number of flowers cluster^{-1}, number of fruits cluster^{-1} and length of fruit of tomato

Treatment	Number of clusters plant^{-1}	Number of flowers cluster^{-1}	Number of fruits cluster^{-1}	Length of fruit (cm)
N_0	5.26 d	4.79 d	2.93 c	4.61 d
N_1	9.15 b	6.39 b	5.59 b	5.53 b
N_2	10.93 a	6.72 a	6.48 a	5.46 c
N_3	8.70 c	6.23 c	5.70 b	5.95 a
LSD $_{(0.05)}$	0.24	0.11	0.24	0.03
CV %	5.89	6.88	4.75	6.57

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

N_0: Control, N_1: 100 kg nitrogen ha^{-1}, N_2: 120 kg nitrogen ha^{-1}, N_3: 140 kg nitrogen ha^{-1}

Table 7. Effect of zinc on number of clusters plant^{-1}, number of flowers cluster^{-1}, number of fruits cluster^{-1} and length of fruit of tomato

Treatment	Number of clusters plant^{-1}	Number of flowers cluster^{-1}	Number of fruits cluster^{-1}	Length of fruit (cm)
Zn_0	6.18 c	5.47 c	3.93 c	5.04 c
Zn_1	8.43 b	6.05 b	5.43 b	5.27 b
Zn_2	10.93 a	6.57 a	6.18 a	5.86 a
LSD $_{(0.05)}$	0.20	0.09	0.20	0.02
CV %	5.89	6.88	4.75	6.57

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 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}

Table 8. Combined effect of nitrogen and zinc on number of clusters plant^{-1}, number of flowers cluster^{-1}, number of fruits cluster^{-1} and length of fruit of tomato

Treatment	Number of clusters plant^{-1}	Number of flowers cluster^{-1}	Number of fruits cluster^{-1}	Length of fruit (cm)
N_0Zn_0	4.93 h	4.52 i	2.93 f	4.23 i
N_0Zn_1	4.93 h	4.77 h	2.93 f	4.41 h
N_0Zn_2	5.93 g	5.10 g	2.93 f	5.21 g
N_1Zn_0	6.59 ef	5.66 f	3.93 e	5.29 f
N_1Zn_1	8.93 d	6.60 c	5.93 c	5.60 c
N_1Zn_2	11.93 b	6.92 b	6.93 b	5.71 b
N_2Zn_0	6.93 e	5.96 e	4.59 d	5.35 e
N_2Zn_1	10.93 c	6.69 c	6.93 b	5.66 b
N_2Zn_2	14.93 a	7.52 a	7.93 a	6.86 a
N_3Zn_0	6.26 fg	5.76 f	4.26 de	5.27 f
N_3Zn_1	8.93 d	6.17 d	5.93 c	5.43 d
N_3Zn_2	10.93 c	6.77 bc	6.93 b	5.68 b
LSD $_{(0.05)}$	0.41	0.19	0.41	0.05
CV %	5.89	6.88	4.75	6.57

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

N_0: Control
N_1: 100 kg nitrogen ha^{-1}
N_2: 120 kg nitrogen ha^{-1}
N_3: 140 kg nitrogen ha^{-1}

Zn_0: Control
Zn_1: 1 kg zinc ha^{-1}
Zn_2: 2 kg zinc ha^{-1}

4.9 Length of fruit

Due to different levels of nitrogen application significant difference was found (Appendix VI). The maximum length of fruit (5.95 cm) was obtained from N_3 (140 kg nitrogen ha^{-1}) treatment and followed by (5.53 cm) N_1 treatment. On the other hand the minimum length of fruit (4.61 cm) was found from N_0

(Control) treatment (Table 6). Huett (1993) with tomato cv. Flora-Dade on krasnozem soils to examine the effects of N and agreed with the results.

The significant difference was found due to the application of different levels of zinc (Appendix VI). The maximum length of fruit (5.86 cm) was found from Zn_2 (2 kg zinc ha^{-1}) treatment and followed by (5.27 cm) Zn_1 treatment. On the other hand, the minimum length of fruit (5.04 cm) was recorded from Zn_0 (Control) treatment (Table 7).

In case of combined effect of different nitrogen and zinc application significant difference was also observed (Appendix VI). The maximum length of fruit (6.86 cm) was obtained from N_2Zn_2 (120 kg nitrogen $ha^{-1}$and 2 kg zinc ha^{-1}) treatment combination. On the other hand, the minimum length of fruit (4.43 cm) was recorded from N_0Zn_0 (Control) treatment combination (Table 8).

4.10 Diameter of fruit

Due to different levels of nitrogen application significant difference was found (Appendix VII). The maximum diameter of fruit (6.16 cm) was obtained from N_2 (120 kg nitrogen ha^{-1}) treatment and followed by (6.05 cm) N_3 treatment. On the other hand the minimum diameter of fruit (4.38 cm) was found from N_0 (Control) treatment (Table 9).

The significant difference was observed due to the application of zinc (Appendix VII). The maximum diameter of fruit (5.90 cm) was found from Zn_1 (1 kg zinc ha^{-1}) treatment and followed by (5.64 cm) Zn_2 treatment. On the other hand, the minimum diameter of fruit (5.40 cm) was recorded from Zn_0 (Control) treatment (Table 10).

From the combined effect of different levels of nitrogen and zinc application significant difference was also found (Appendix VII). The maximum diameter of fruit (6.51 cm) was obtained from N_2Zn_2 (120 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1}) treatment combination. On the other hand, the minimum diameter of fruit

(3.94 cm) was recorded from N_0Zn_0 (control) treatment combination (Table 11).

4.11 Fresh weight of fruit

In case of nitrogen application significant difference was found (Appendix VII). The maximum fresh weight of fruit (73.90 g) was obtained from N_2 (120 kg nitrogen ha^{-1}) treatment and followed by (70.67 g) N_3 treatment which is statistically identical to (70.12 g) N_0 treatment. On the other hand the minimum fresh weight of fruit (39.79 g) was found from N_0 (Control) treatment (Table 9). Khalil *et al.* (2001) conducted an experiment in Peshawar, Pakistan and agreed with the similar results due to nitrogen application. Gupta and Sengar (2000) found that tomato cv. Pusa Gaurav was treated with N and found increased individual fresh weight of tomato.

Due to the application of different levels zinc significant difference was observed (Appendix VII). The maximum fresh weight of fruit (77.79 g) was found from Zn_2 (2 kg zinc ha^{-1}) treatment and followed by (66.29 g) Zn_1 treatment. On the other hand, the minimum fresh weight of fruit (46.79 g) was recorded from Zn_0 (Control) treatment (Table 10). Paithankar *et al.* (2004) reported in tomato highest number of fruits and weight due to micro nutrient application.

The significant difference was found from the combined effect of different levels of nitrogen and zinc application (Appendix VII). The maximum fresh weight of fruit (91.79 g) was obtained from N_2Zn_2 (120 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1}) treatment combination. On the other hand, the minimum fresh weight of fruit (32.79 g) was recorded from Zn_0N_0 (Control) treatment combination (Table 11). Hossain and Mohanty (1999) found highest fruit weight and total yield. Huett (1993) with tomato cv. Flora-Dade on krasnozem soils to examine the effects of N and agreed with the results.

4.12 Dry matter content of fruit

At different levels of nitrogen application significant difference on dry matter was found (Appendix VII). The maximum dry matter content of fruit (11.31 %) was obtained from N_2 (120 kg nitrogen ha^{-1}) treatment and followed by (10.68 %) N_1 treatment. On the other hand the minimum dry matter content of fruit (8.08 %) was found from N_0 (Control) treatment (Table 9). Gupta and Sengar (2000) found that tomato cv. Pusa Gaurav was leaf development and dry matter accumulation were greatest N and declined at higher concentrations.

Table 9. Effect of nitrogen on diameter of fruit, fresh weight of fruit and dry matter content of fruit of tomato

Treatment	Diameter of fruit (cm)	Fresh weight of fruit (g)	Dry matter content of fruit (%)
N_0	4.38 d	39.79 c	8.08 d
N_1	6.00 c	70.12 b	10.68 b
N_2	6.16 a	73.90 a	11.31 a
N_3	6.05 b	70.67 b	10.40 c
LSD $_{(0.05)}$	0.01	1.92	0.17
CV %	6.30	7.10	5.75

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

N_0: Control, N_1: 100 kg nitrogen ha^{-1}, N_2: 120 kg nitrogen ha^{-1}, N_3: 140 kg nitrogen ha^{-1}

The significant difference was observed due to the application of zinc (Appendix VII). The maximum dry matter content of fruit (11.08 %) was found from Zn_2 (2 kg zinc ha^{-1}) treatment and followed by (10.06 %) Zn_1 treatment. On the other hand, the minimum dry matter content of fruit (9.21 %) was recorded from Zn_0 (Control) treatment (Table 10). Salam *et al.* (2010) found the highest pulp weight (88.14%), dry matter content and TSS from Zn application.

Table 10. Effect of zinc on diameter of fruit, fresh weight of fruit and dry matter content of fruit of tomato

Treatment	Diameter of fruit (cm)	Fresh weight of fruit (g)	Dry matter content of fruit (%)
Zn_0	5.40 c	46.79 c	9.21 c
Zn_1	5.90 a	66.29 b	10.06 b
Zn_2	5.64 b	77.79 a	11.08 a
LSD $_{(0.05)}$	0.01	1.66	0.15
CV %	6.30	7.10	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 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}

The significant difference was observed due to the combined effect of different nitrogen and zinc application (Appendix VII). The maximum dry matter content of fruit (13.10 %) was obtained from N_2Zn_2 (120 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1}) treatment combination. On the other hand, the minimum dry matter content of fruit (7.73 %) was recorded from N_0Zn_0 (Control) treatment combination (Table 11). Singh *et al.* (2000) conducted an experiment and supported the similar results. Kooner and Randhawa (1990) agreed with the results also. Staneve (1983) conducted an experiment to investigate the effect of nitrogen supply on photosynthesis, leaf area and total dry matter in tomato and found that photosynthesis was inhabited by N deficiency.

Table 11. Combined effect of nitrogen and zinc on diameter of fruit, fresh weight of fruit and dry matter content of fruit of tomato

Treatment	Diameter of fruit (cm)	Fresh weight of fruit (g)	Dry matter content of fruit (%)
N_0Zn_0	3.94 k	32.79 h	7.73 i
N_0Zn_1	4.51 j	38.79 g	8.16 h
N_0Zn_2	4.71 i	47.79 f	8.37 h
N_1Zn_0	5.88 h	48.79 ef	9.58 g
N_1Zn_1	6.03 e	75.79 c	10.73 de
N_1Zn_2	6.24 b	85.79 b	11.73 b
N_2Zn_0	5.92 g	54.12 d	9.98 f
N_2Zn_1	6.06 d	75.79 c	10.86 cd
N_2Zn_2	6.51 a	91.79 a	13.10 a
N_3Zn_0	5.88 h	51.45 de	9.55 g
N_3Zn_1	5.99 f	74.79 c	10.52 e
N_3Zn_2	6.14 c	85.79 b	11.15 c
LSD $_{(0.05)}$	0.02	3.33	0.30
CV %	6.30	7.10	5.75

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

N_0: Control
N_1: 100 kg nitrogen ha^{-1}
N_2: 120 kg nitrogen ha^{-1}
N_3: 140 kg nitrogen ha^{-1}

Zn_0: Control
Zn_1: 1 kg zinc ha^{-1}
Zn_2: 2 kg zinc ha^{-1}

4.13 Chlorophyll content in leaf

In case of different levels of nitrogen application significant difference was found (Appendix VIII). The maximum chlorophyll content in leaf (63.22 %) was obtained from N_3 (140 kg nitrogen ha^{-1}) treatment and followed by (59.61 %) N_2 treatment. On the other hand the minimum chlorophyll content in leaf

(53.38 %) was found from N_0 (Control) treatment (Table 12). Scholberg (2000) conducted an experiment and agreed with the results.

Due to different levels of nitrogen application significant difference was observed (Appendix VIII). The maximum chlorophyll content in leaf (62.34 %) was found from Zn_2 (2 kg zinc ha^{-1}) treatment and followed by (57.76 %) Zn_1 treatment. On the other hand, the minimum chlorophyll content in leaf (56.50 %) was recorded from Zn_0 (control) treatment (Table 13). Salam *et al.* (2010) found the highest pulp weight (88.14%), chlorophyll-a, chlorophyll-b, from Zn and B combine application.

The significant difference was found due to the combined effect of different levels of nitrogen and zinc application (Appendix VIII). The maximum chlorophyll content in leaf (71.48 %) was obtained from N_3Zn_2 (140 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1}) treatment combination. On the other hand, the minimum chlorophyll content in leaf (51.83 %) was recorded from N_0Zn_0 (Control) treatment combination (Table 14).

4.14 TSS (Total Soluble Solid)

The significant difference was found due to the application of nitrogen (Appendix VIII). The maximum TSS of fruit (8.02 %) was obtained from N_2 (120 kg nitrogen ha^{-1}) treatment and followed by (7.60 %) N_1 treatment. On the other hand the minimum TSS of fruit (6.68 %) was found from N_0 (Control) treatment (Table 12). Gupta and Sengar (2000) found that tomato cv. Pusa Gaurav was treated with N and found increased dry matter content and TSS in tomato.

In case of zinc application significant difference was observed (Appendix VIII). The maximum TSS of fruit (7.93 %) was found from Zn_2 (2 kg zinc ha^{-1}) treatment and followed by (7.34 %) Zn_1 treatment. On the other hand, the minimum TSS of fruit (7.11 %) was recorded from Zn_0 (control) treatment (Table 13). Salam*et al.* (2010) found the highest pulp weight (88.14%), dry matter content, TSS, acidity, chlorophyll-a, chlorophyll-b, from Zn and B combine application.

Table 12. Effect of nitrogen on chlorophyll content in leaf, TSS of fruit and vitamin C content of fruit of tomato

Treatment	Chlorophyll content in leaf (%)	TSS (%)	Vitamin C content (mg /100 g)
N_0	53.38 d	6.68 d	10.53 d
N_1	59.26 c	7.60 b	12.49 b
N_2	59.61 b	8.02 a	13.94 a
N_3	63.22 a	7.53 c	11.08 c
$LSD_{(0.05)}$	0.12	0.03	0.31
CV %	7.12	6.11	9.15

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

N_0: Control, N_1: 100 kg nitrogen ha^{-1}, N_2: 120 kg nitrogen ha^{-1}, N_3: 140 kg nitrogen ha^{-1}

Table 13. Effect of zinc on chlorophyll content in leaf, TSS of fruit and vitamin C content of fruit of tomato

Treatment	Chlorophyll content in leaf (%)	TSS (%)	Vitamin C content (mg /100 g)
Zn_0	56.50 c	7.11 c	12.07 c
Zn_1	57.76 b	7.34 b	13.63 b
Zn_2	62.34 a	7.93 a	14.84 a
$LSD_{(0.05)}$	0.11	0.02	0.23
CV %	7.12	6.11	9.15

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 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}

The significant difference was found due to the combined effect of different nitrogen and zinc application (Appendix VIII). The maximum TSS of fruit (8.93 %) was obtained from N_2Zn_2 (120 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1}) treatment combination. On the other hand, the minimum TSS of fruit (6.3 %) was recorded from N_0Zn_0 (Control) treatment combination (Table 14). Kooner and Randhawa (1990) agreed with the results also.

Table 14. Combined effect of nitrogen and zinc on chlorophyll content in leaf, TSS of fruit and vitamin C content of fruit of tomato

Treatment	Chlorophyll content in leaf (%)	TSS (%)	Vitamin C content (mg /100 g)
N_0Zn_0	51.83 j	6.30 i	11.75 g
N_0Zn_1	53.26 i	6.48 h	12.35 f
N_0Zn_2	55.05 h	7.28 g	12.47 f
N_1Zn_0	57.99 g	7.36 f	13.04 e
N_1Zn_1	59.03 e	7.67 c	14.28 c
N_1Zn_2	61.03 c	7.78 b	16.16 a
N_2Zn_0	58.26 f	7.42 e	13.63 d
N_2Zn_1	59.93 d	7.73 b	14.63 bc
N_2Zn_2	61.83 b	8.93 a	16.55 a
N_3Zn_0	57.93 g	7.34 f	13.02 e
N_3Zn_1	58.83 e	7.5 d	14.25 c
N_3Zn_2	71.48 a	7.75 b	14.94 b
$LSD_{(0.05)}$	0.22	0.05	0.43
CV %	7.12	6.11	9.15

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

N_0: Control
N_1: 100 kg nitrogen ha^{-1}
N_2: 120 kg nitrogen ha^{-1}
N_3: 140 kg nitrogen ha^{-1}

Zn_0: Control
Zn_1: 1 kg zinc ha^{-1}
Zn_2: 2 kg zinc ha^{-1}

4.15 Vitamin C content

In case of different levels of nitrogen application significant difference was found (Appendix VIII). The maximum vitamin C content (13.94 mg/100 g) was obtained from N_2 (120 kg nitrogen ha^{-1}) treatment and followed by (12.49 mg/100 g) N_1 treatment. On the other hand the minimum vitamin C content (11.08 mg/100 g) was found from N_0 (Control) treatment (Table 12). Awad *et al.* (2001) showed that increasing N fertilizer rate enhanced total yield and vitamin C content of both mono and mixed crops. Staneve (1983) conducted an experiment to investigate the effect of nitrogen supply on photosynthesis, and vitamin C content in fruit of tomato and found that vitamin C content was reduced by nutrient deficiency.

The significant difference was observed due to the application of different levels of zinc (Appendix VIII). The maximum vitamin C content (14.84 mg/100 g) was found from Zn_2 (2 kg zinc ha^{-1}) treatment and followed by (13.63 mg/100 g) Zn_1 treatment. On the other hand, the minimum vitamin C content (12.07 mg/100 g) was recorded from Zn_0 (Control) treatment (Table 13). Sivaiah *et al*. (2013) conducted an experiment and found that combined application of micronutrients controls all the physiological activities which helps in photosynthesis and produced the maximum fruit yield followed by the application of boron and zinc combined.

Due to the combined effect of different levels of nitrogen and zinc application significant difference was found (Appendix VIII). The maximum vitamin C content (16.16 mg/100 g) was obtained from N_2Zn_2 (120 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1}) treatment combination which is statistically identical to N_1Zn_2 (100 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1}) treatment combination. On the other hand, the minimum vitamin C content (11.75 mg/100 g) was recorded from N_0Zn_0 (Control) treatment combination (Table 14).

4.16 Yield plant^{-1}

At different levels of nitrogen application significant difference on yield per plant was found (Appendix IX). The highest yield plant^{-1} (2.44 kg) was obtained from N_2 (120 kg nitrogen ha^{-1}) treatment and followed by (2.26 kg) N_1 treatment which is statistically identical to N_3 treatment. On the other hand the lowest yield plant^{-1} (1.73 kg) was found from N_0 (Control) treatment (Table 15). Ceylan *et al.* (2001) conducted a field experiment to assess the effect of ammonium nitrate and urea fertilizers on nitrogen uptake and accumulation in tomato plants under field conditions and supported the similar results. Scholberg (2000) conducted an experiment and supported the results.

The significant difference was observed due to the application of zinc (Appendix IX). The highest yield plant^{-1} (2.43 kg) was found from Zn_2 (2 kg zinc ha^{-1}) treatment and followed by (2.17 kg) Zn_1 treatment. On the other hand, the lowest yield plant^{-1} (1.88 kg) was recorded from Zn_0 (Control) treatment (Table 16). Ejaz *et al.* (2011) said that, It is confirmed from the results that combination of macro-nutrients and micro-nutrients as foliar application has the ability to enhance the growth and yield of tomato positively.

In case of combined effect of different levels of nitrogen and zinc application significant difference was observed (Appendix IX). The highest yield plant^{-1} (2.76 kg) was obtained from N_2Zn_2 (120 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1}) treatment combination. On the other hand, the lowest yield plant^{-1} (1.59 kg) was recorded from N_0Zn_0 (Control) treatment combination (Table 17). Bot *et al.* (2001) carried out an experiment and supported the results. Awad *et al.* (2001) showed that increasing N fertilizer rate enhanced total yield and net assimilation rate of both mono and mixed crops.

4.17 Yield plot^{-1}

The significant difference was found due to the application of different levels of nitrogen (Appendix IX). The highest yield plot^{-1}(24.57 kg) was obtained from N_2 (120 kg nitrogen ha^{-1}) treatment and followed by (21.89 kg) N_3

treatment which is statistically similar to (22.57 kg) N_2 treatment. On the other hand the lowest yield plot^{-1} (16.11 kg) was found from N_0 (Control) treatment (Table 15). Nawaz *et al.* (2012) found the maximum number of fruit per plant was observed when plots received nitrogen fertilizers. Kirimi *et al.* (2011) investigated the effects of nitrogen levels on tomato fruit yield and quality in two seasons.

Due to the application of different levels of zinc significant difference was observed (Appendix IX). The highest yield plot^{-1} (24.59 kg) was found from Zn_2 (2 kg zinc ha^{-1}) treatment and followed by (21.38 kg) Zn_1 treatment. On the other hand, the lowest yield plot^{-1} (17.99 kg) was recorded from Zn_0 (Control) treatment (Table 16). Harris and Mathuma (2015) supported the results.

In case of combined effect of different levels of nitrogen and zinc application significant difference was found (Appendix IX). The highest yield plot^{-1} (28.51 kg) was obtained from N_2Zn_2 (120 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1}) treatment combination. On the other hand, the lowest yield plot^{-1} (14.42 kg) was recorded from N_0Zn_0 (Control) treatment combination (Table 17). Balemi (2008) investigated the response of tomato cultivars varying in growth habit to rates of Nitrogen (N) and resulted in significantly higher total as well as marketable fruit yield of the tomato.

4.18 Yield

The significant difference was found due to the application of different levels of nitrogen (Appendix IX). The highest yield (66.15 ton) was obtained from N_2 (120 kg nitrogen ha^{-1}) treatment and followed by (60.19 ton) N_1 treatment which is statistically identical to (58.32 ton) N_3 treatment. On the other hand the lowest yield (42.25 ton) was found from N_0 (control) treatment (Table 15). Nawaz *et al.* (2012) found the maximum number of fruit per plant was observed when plots received nitrogen fertilizers. Khalil *et al.* (2001) conducted an experiment in Peshawar, Pakistan in the summer to determine the appropriate nitrogen fertilizer for maximum tomato yield and its effects on various agronomic characters of tomato and supported the similar results.

Table 15. Effect of nitrogen on yield plant^{-1}, yield plot^{-1} and yield hectare^{-1} of tomato plant

Treatment	Yield plant^{-1} (kg)	Yield plot^{-1} (kg)	Yield (t ha^{-1})
N_0	1.73 c	16.11 c	42.25 c
N_1	2.26 b	22.57 b	60.19 b
N_2	2.44 a	24.71 a	66.15 a
N_3	2.21 b	21.89 b	58.32 b
LSD $_{(0.05)}$	0.06	0.75	2.08
CV %	5.61	6.34	6.18

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

N_0: Control, N_1: 100 kg nitrogen ha^{-1}, N_2: 120 kg nitrogen ha^{-1}, N_3: 140 kg nitrogen ha^{-1}

Table 16. Effect of zinc on yield plant^{-1}, yield plot^{-1} and yield hectare^{-1} of tomato plant

Treatment	Yield plant^{-1} (kg)	Yield plot^{-1} (kg)	Yield (t ha^{-1})
Zn_0	1.88 c	17.99 c	47.47 c
Zn_1	2.17 b	21.38 b	56.90 b
Zn_2	2.43 a	24.59 a	65.82 a
LSD $_{(0.05)}$	0.05	0.64	1.80
CV %	5.61	6.34	6.18

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 kg zinc ha^{-1}, Zn_2: 2 kg zinc ha^{-1}

Table 17. Combined effect of nitrogen and zinc on yield plant^{-1}, yield plot^{-1} and yield hectare^{-1} of tomato plant

Treatment	Yield plant^{-1} (kg)	Yield plot^{-1} (kg)	Yield (t ha^{-1})
N_0Zn_0	1.59 i	14.42 i	37.55 i
N_0Zn_1	1.77 h	16.62 h	43.67 h
N_0Zn_2	1.83 gh	17.30 gh	45.55 gh
N_1Zn_0	1.93 fg	18.56 fg	49.06 fg
N_1Zn_1	2.25 d	22.31 d	59.46 d
N_1Zn_2	2.62 b	26.84 b	72.05 b
N_2Zn_0	2.08 e	20.38 e	54.11 e
N_2Zn_1	2.49 c	25.26 c	67.67 c
N_2Zn_2	2.76 a	28.51 a	76.68 a
N_3Zn_0	1.94 f	18.60 f	49.17 f
N_3Zn_1	2.17 de	21.35 de	56.80 de
N_3Zn_2	2.53 bc	25.74 bc	69.00 bc
LSD $_{(0.05)}$	0.01	1.29	3.61
CV %	5.61	6.34	6.18

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

N_0: Control
N_1: 100 kg nitrogen ha^{-1}
N_2: 120 kg nitrogen ha^{-1}
N_3: 140 kg nitrogen ha^{-1}

Zn_0: Control
Zn_1: 1 kg zinc ha^{-1}
Zn_2: 2 kg zinc ha^{-1}

Due to the application of different levels of zinc significant difference was observed (Appendix IX). The highest yield (65.82 ton) was found from Zn_2 (2 kg zinc ha^{-1}) treatment and followed by (56.90 ton) Zn_1 treatment. On the other hand, the lowest yield (47.47 ton) was recorded from Zn_0 (Control) treatment (Table 16). Ejaz *et al.* (2011) found that individual application of nutrient provide better results as compared to control but their combined effect provided substantial results in plant heights, number of leaves, no of flowers, no of fruits, average fruit weight and yield per plant.

In case of combined effect of different levels of nitrogen and zinc application significant difference was found (Appendix IX). The highest yield (76.68 ton) was obtained from N_2Zn_2 (120 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1}) treatment combination. On the other hand, the lowest yield (37.55 ton) was recorded from N_0Zn_0 (control) treatment combination (Table 17). Nawaz *et al.* (2012) found that, total yield was increased as compared to control when plots received nitrogen and zinc combinely.

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from October, 2015 to March, 2016 to find out the effect of nitrogen and zinc on growth and yield of tomato. The experiment consisted of two factors, Factor A: Four levels of nitrogen. The treatments are N_0: Control; N_1: 100 kg nitrogen ha^{-1}; N_2: 120 kg nitrogen ha^{-1} and N_3: 140 kg nitrogen ha^{-1}. Factor B: Three levels of zinc application. The treatments are Zn_0: Control, Zn_1: 1 kg zinc ha^{-1} and Zn_2: 2 kg zinc ha^{-1}. There were 12 treatment combinations. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth, yield contributing characters and yield were recorded to find out the suitable combination of nitrogen and zinc for higher yield of tomato.

In case of nitrogen application the highest plant height at 60 DAT (80.88 cm), the maximum number of leaves per plant at 60 DAT (73.22), the maximum number of branches per plant (6.88), the maximum canopy size (79.54 cm), the maximum size of stem diameter (2.40 cm), the maximum number of clusters $plant^{-1}$ (10.93), the maximum number of flowers $cluster^{-1}$ (6.72), the maximum number of fruits $cluster^{-1}$ (6.48), the maximum diameter of fruit (6.16 cm), the maximum fresh weight of fruit (73.90 g), the maximum dry matter content of fruit (11.31%), the highest TSS (8.02%), the maximum vitamin C content (13.94 mg/100 g), the maximum yield of fruit $plant^{-1}$ (2.44 kg), the maximum yield of fruit $plot^{-1}$ (24.71 kg) and the maximum yield (66.15 t/ha) were recorded from the 120 kg nitrogen ha^{-1} that is N_2 treatment. The highest length of fruit (5.95 cm), the maximum chlorophyll content in leaf (63.22 %), were recorded from the 140 kg nitrogen ha^{-1} that is N_3 treatment. On the other hand, the shortest plant height at 60 DAT (68.55 cm), the minimum number of leaves per plant at 60 DAT (59.11), the minimum number of branches per plant

(4.70), the minimum size of canopy (62.23 cm), the minimum size of stem diameter (1.98 cm), the minimum number of clusters plant^{-1} (5.26), the minimum number of flowers cluster^{-1} (4.79), the minimum number of fruits cluster^{-1} (2.93), the lowest length of fruit (4.61 cm), the lowest diameter of fruit (4.38 cm), the minimum fresh weight of fruit (39.79 g), the minimum dry matter content of fruit (8.08 %), the minimum chlorophyll content in leaf (53.38 %), the lowest TSS (6.68 %), the minimum vitamin C content (11.08 mg/100 g), the minimum yield of fruit plant^{-1} (1.73 kg), the minimum yield of fruit plot^{-1} (16.11 kg) and the minimum yield (42.25 t/ha) were recorded from the control treatment that is N_0 treatment.

In case of zinc application, the highest plant height at 60 DAT (90.50 cm), the maximum number of leaves per plant at 60 DAT (76.16), the maximum number of branches per plant (6.82), the maximum size of canopy (81.31 cm), the maximum size of stem diameter (2.40 cm), the maximum number of clusters plant^{-1} (10.93), the maximum number of flowers cluster^{-1} (6.57), the maximum number of fruits cluster^{-1} (6.18), the highest length of fruit (5.86 cm), the maximum fresh weight of fruit (77.79 g), the maximum dry matter content of fruit (11.08 %), the maximum chlorophyll content in leaf (62.34 %), the highest TSS (7.93%), the maximum vitamin C content (14.84 mg/100 g), the maximum yield of fruit plant^{-1} (2.43 kg), the maximum yield of fruit plot^{-1} (24.59 kg) and the maximum yield (65.82 t/ha) were recorded from the treatment of 2 kg zinc ha^{-1} that is Zn_2 treatment.

The highest diameter of fruit (5.90 cm) was recorded from 1 kg zinc ha^{-1} that is Zn_1 treatment. On the other hand, the shortest plant height at 60 DAT (90.50 cm), the minimum number of leaves per plant at 60 DAT (76.16), the minimum number of branches per plant (6.82), the minimum size of canopy (81.31 cm), the minimum size of stem diameter (2.40 cm), the minimum number of clusters plant^{-1} (10.93), the minimum number of flowers cluster^{-1} (6.57), the minimum number of fruits cluster^{-1} (6.18), the lowest length of fruit (5.27 cm), the lowest diameter of fruit (5.90 cm), the minimum fresh weight of fruit (77.79 g), the minimum dry matter content of fruit (11.08 %), the minimum chlorophyll content in leaf (62.34 %), the lowest TSS (7.93%), the minimum vitamin C content (12.07 mg/100 g), the minimum yield of fruit plant^{-1} (2.43 kg), minimum yield of fruit plot^{-1} (24.59 kg) and the minimum yield (65.82 t/ha) were recorded from the Zn_0 (control) treatment.

In case of combined effect of nitrogen and zinc, the longest plant height at 60 DAT (99.00 cm), the maximum number of leaves per plant at 60 DAT (88.66), the maximum number of branches per plant (7.77), the maximum canopy size (92.00 cm), the maximum size of stem diameter (2.61 cm), the maximum number of clusters plant^{-1} (14.93), the maximum number of flowers cluster^{-1} (7.52), the maximum number of fruits cluster^{-1} (7.93), the maximum length of fruit (6.86 cm), the maximum diameter of fruit (6.51), the maximum fresh weight of fruit (91.79 g), the maximum dry matter content of fruit (13.10 %), the highest TSS (8.93 %), the maximum vitamin C content (16.16 mg/100 g), maximum yield of fruit plant^{-1} (2.76 kg), the maximum yield of fruit plot^{-1} (28.51 kg) and the maximum yield (76.68 t/ha) were recorded from the 120 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1} and that is N_2Zn_2 treatment combination.

The maximum chlorophyll content in leaf (71.48 %) were recorded from N_3Zn_2 treatment combination. On the other hand, the shortest plant height at 60 DAT (53.00 cm), the minimum number of leaves per plant at 60 DAT (50.66), the minimum number of branches per plant (3.77), the minimum size of canopy (58.00 cm), the minimum size of stem diameter (1.86 cm), the minimum number of clusters plant^{-1} (4.93), the minimum number of flowers cluster^{-1} (4.52), the minimum number of fruits cluster^{-1} (2.93), the lowest length of fruit (4.23 cm), the lowest diameter of fruit (3.94 cm), the minimum fresh weight of fruit (32.79 g), the minimum dry matter content of fruit (7.73 %), the minimum chlorophyll content in leaf (51.83 %), the lowest TSS (6.30 %), the minimum vitamin C content (11.75 mg/100 g), the minimum yield of fruit plant^{-1} (1.59 kg), the minimum yield of fruit plot^{-1} (14.42 kg) and the minimum yield (37.55 t/ha) were recorded from N_0Zn_0 (control) treatment combination.

Conclusion

From the present study it was found that application of 120 kg nitrogen ha^{-1} and 2 kg zinc ha^{-1} (N_2Zn_2) treatment combination performed the highest yield (76.68 t ha^{-1}) of tomato. Considering the findings of the experiment, it can be concluded that, the (N_2Zn_2) treatment combination is the suitable application for higher yield of tomato.

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Appendices

APPENDICES

Appendix I. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from October 2015 to May 2016

Month	Air temperature (^0C)		Relative Humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
October, 15	29.18	18.26	81	39
November, 15	25.82	16.04	78	0
December, 15	22.4	13.5	74	0
January, 16	24.5	12.4	68	0
February, 16	27.1	16.7	67	3
March, 16	31.4	19.6	54	11
April, 16	35.3	22.4	51	15
May, 16	38.2	23.2	62	17

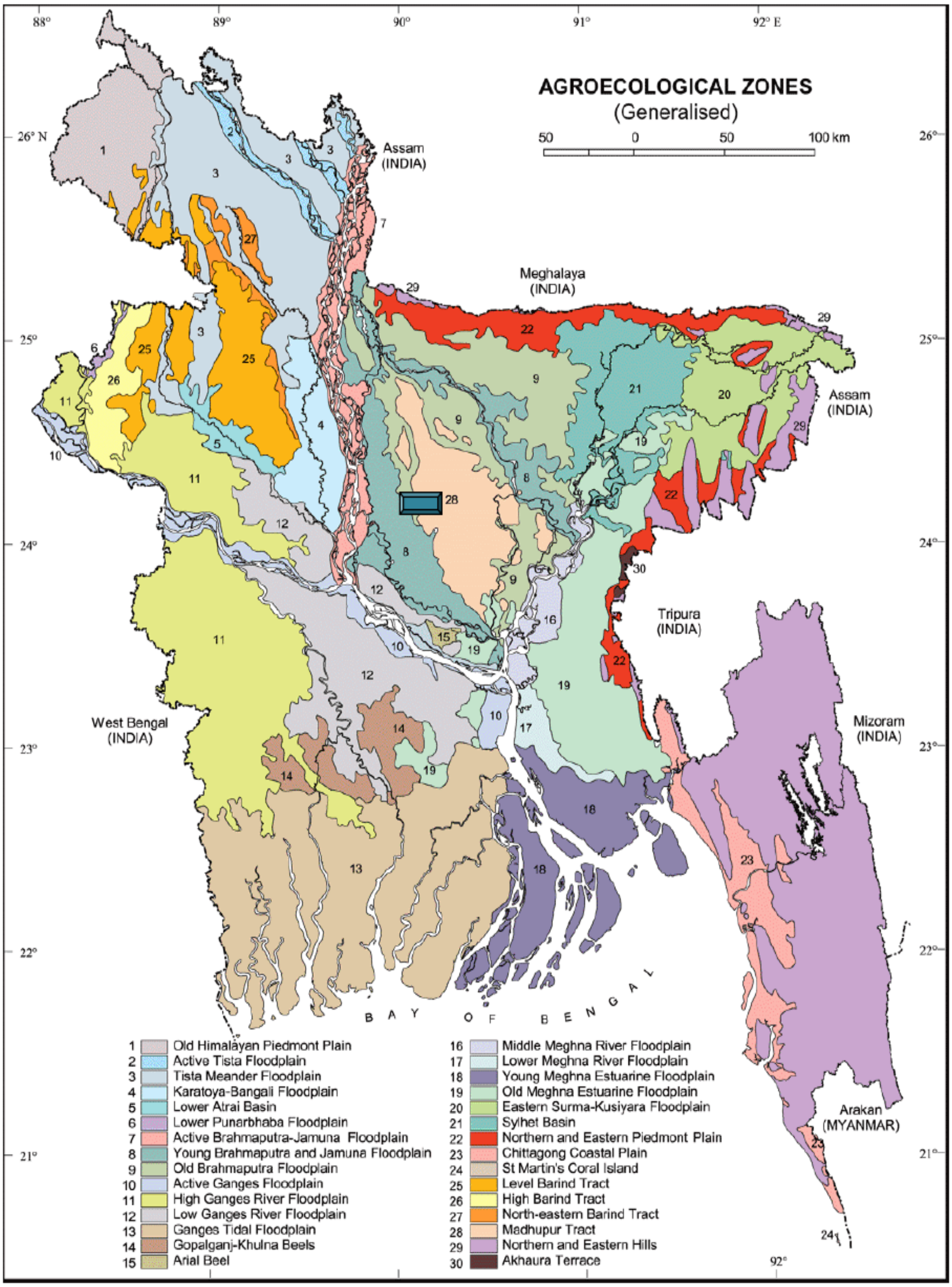
Source: Bangladesh Metrological Department (Climate and weather division) Agargaon, Dhaka

Appendix II. Morphological characteristics, AEZ map of Bangladesh showing experimental site, mechanical and chemical analysis of soil of the experimental plot

A. Morphological Characteristics

Morphological features	Characteristics
Location	Horticulture Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow redbrown terrace soil
Land Type	Medium high land
Soil Series	Tejgaon
Topography	Fairly leveled
Flood Level	Above flood level
Drainage	Well drained

B. Experimental site at Sher-e-Bangla Agricultural University, Dhaka-1207



The AEZ map of Bangladesh showing experimental site

C. Mechanical analysis

Constituents	Percentage (%)
Sand	28.78
Silt	42.12
Clay	29.1

D. Chemical analysis

Soil properties	Amount
Soil pH	5.8
Organic carbon (%)	0.95
Organic matter (%)	0.77
Total nitrogen (%)	0.075
Available P (µ gm/gm)	18.49
Exchangeable K (µ gm/gm)	0.07
Available S (µ gm/gm)	20.82
Available Fe (µ gm/gm)	229
Available Zn (µ gm/gm)	4.48
Available Mg (µ gm/gm)	0.825
Available Na (µ gm/gm)	0.32
Available B (µ gm/gm)	0.94

Source: Soil Resource Development Institute (SRDI)

Appendix III. Analysis of variance of data on plant height at different days after transplanting of tomato

Source of variation	Degrees of freedom (df)	Mean square of plant height at				
		20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	2.111	8.583	52.000	117.530	218.110
Factor A (Nitrogen)	3	7.888	25.556*	113.296*	174.330*	287.060*
Factor B (Zinc)	2	63.861	254.333*	796.333*	1292.030*	2629.860*
Interaction (A × B)	6	3.416	2.778*	13.741*	6.030*	23.120**
Error	22	0.414	1.583	10.727	18.440	29.930

DAT= Days after transplanting

** : Significant at 1% level of probability;   * : Significant at 5% level of probability

Appendix IV. Analysis of variance of data on number of leaves at different days after transplanting of tomato

Source of variation	Degrees of freedom (df)	Mean square of number of leaves at				
		20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	1.000	0.583	0.694	14.583	6.361
Factor A (Nitrogen)	3	0.222	10.250*	156.185**	222.398*	318.102*
Factor B (Zinc)	2	1.083	20.333*	329.194*	624.333*	830.861*
Interaction (A × B)	6	0.083	4.888*	31.046*	61.370**	94.713**
Error	22	0.303	0.583	14.149	17.341	26.301

** : Significant at 1% level of probability;   * : Significant at 5% level of probability

Appendix V. Analysis of variance of data on number of branches plant^{-1}, canopy size and stem diameter of tomato

Source of variation	Degrees of freedom (df)	Mean square		
		Number of branches plant^{-1}	Canopy size (cm)	Stem diameter (cm)
Replication	2	3.741	2.730	1.732
Factor A (Nitrogen)	3	8.410*	294.407*	0.073**
Factor B (Zinc)	2	5.880*	1336.58*	0.583*
Interaction (A × B)	6	0.133*	78.213*	0.0096**
Error	22	7.270	0.424	4.559

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix VI. Analysis of variance of data on number of clusters plant^{-1}, number of flowers cluster^{-1}, number of fruits cluster^{-1} and length of fruit of tomato

Source of variation	Degrees of freedom (df)	Mean square			
		Number of clusters plant^{-1}	Number of flowers cluster^{-1}	Number of fruits cluster^{-1}	Length of fruit (cm)
Replication	2	6.221	3.192	2.421	2.783
Factor A (Nitrogen)	3	50.546*	6.532*	21.657*	2.844*
Factor B (Zinc)	2	67.750*	3.633*	15.750*	2.167*
Interaction (A × B)	6	6.379*	0.163*	1.824**	0.268*
Error	22	0.060	0.012	0.060	9.460

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix VII. Analysis of variance of data on diameter of fruit, fresh weight of fruit and dry matter content of fruit of tomato

Source of variation	Degrees of freedom (df)	Mean square		
		Diameter of fruit (cm)	Fresh weight of fruit (g)	Dry matter content of fruit (%)
Replication	2	2.352	1.591	2.962
Factor A (Nitrogen)	3	6.441*	2297.070*	17.874*
Factor B (Zinc)	2	0.727*	2947*	10.574*
Interaction (A × B)	6	0.060*	105.741**	0.966*
Error	22	2.973	3.878	0.031

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix VIII. Analysis of variance of data on chlorophyll content in leaf, TSS of fruit and vitamin C content of fruit of tomato

Source of variation	Degrees of freedom (df)	Mean square		
		Chlorophyll content in leaf (%)	TSS (%)	Vitamin C content (mg per 100 g)
Replication	2	1.212	1.454	2.851
Factor A (Nitrogen)	3	149.450*	2.844*	25.621*
Factor B (Zinc)	2	113.477*	2.167*	38.756*
Interaction (A × B)	6	23.064*	0.268*	1.453*
Error	22	0.0169	9.463	1.783

* : Significant at 5% level of probability

Appendix IX. Analysis of variance of data on Yield plant^{-1}, Yield plot^{-1} and yield hectare^{-1} of tomato

Source of variation	Degrees of freedom (df)	Mean square		
		Yield plant^{-1} (kg)	Yield plot^{-1} (kg)	Yield hectare^{-1} (t ha^{-1})
Replication	2	1.831	1.337	7.645
Factor A (Nitrogen)	3	0.842*	121.625*	938.497*
Factor B (Zinc)	2	0.899*	131.010*	1009.870*
Interaction (A × B)	6	0.037**	5.500**	42.422**
Error	22	4.105	0.589	4.5472

** : Significant at 1% level of probability; * : Significant at 5% level of probability