EFFECT OF ZINC AND COPPER ON THE GROWTH AND YIELD OF TOMATO

FATEMATUS JOHURA

DEPARTMENT OF SOIL SCIENCE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

June, 2017

EFFECT OF ZINC AND COPPER ON THE GROWTH AND YIELD OF TOMATO

BY

FATEMATUS JOHURA

REGISTRATION NO. 11-04530

A Thesis

Submitted to the Faculty of Agriculture, Dept. of Soil Science
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

IN

SOIL SCIENCE

SEMESTER: Jan-June, 2017

Approved by:

(Prof. Dr. Md. Asaduzzaman khan)	**(Prof. Dr. Alok Kumar Paul)**
Supervisor	**Co-supervisor**

Dr.Saikat Chowdhury
Chairman
Department of Soil Science
Sher-e-Bangla Agricultural University

Dr.Md.Asaduzzaman khan
Professor
Department of soil science
Sher-e-Bangla Agricultural University
Dhaka, Bangladesh

Ref: Date:

CERTIFICATE

This is to certify that thesis entitle "**EFFECT OF ZINC AND COPPER** ON **THE GROWTH AND YIELD OF TOMATO**(***Solanum lycopersicum***) **"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **SOIL SCIENCE,** embodies the result of a piece of bona fide research work carried out by **FATEMATUS JOHURA, Registration No. 11-04530** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June,2017
Dhaka, Bangladesh

Prof. Dr.Md.Asaduzzaman khan
Department of soil science
Sher-e-Bangla Agricultural University
Supervisor

ACKNOWLEDGEMENTS

All praises are due to Omnipotent"Allah Rabbul Al-Amin" Who enabled me to pursue higher study and to complete the research work as well as to submit the thesis for the degree of Master of Science (M.S.) in Soil Science, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

I would like to express my heartfelt respect, deepest sense of gratitude, profound appreciation and ever indebtedness to my supervisor, ***Professor Dr. Md.Asaduzzaman Khan,*** *Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for his sincere guidance, scholastic supervision, constructive criticism, extending generous help and constant inspiration throughout the course and in preparation of the manuscript of thesis.*

I express my sincere respect to my Co-supervisor, ***Professor Dr. Alok Kumar Paul*** *,Department of Soil Science, Sher-e-Bangla Agricultural University, (SAU), Dhaka for his utmost co-operation, constructive suggestion to conduct the research work as well as preparation of the manuscript of thesis.*

*I express my sincere respect to the Chairman,****Dr.Saikat Chowdhury*** *and all the teachers of Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for providing the facilities to conduct the experiment and for their valuable advice and sympathetic consideration in connection with the study.*

I express my unfathomable tributes, sincere gratitude and heartfelt indebtedness from my core of heart to my parents, and also pleasant to my brother, whose blessing, inspiration, sacrifice, and moral support opened the gate and paved to way of my higher study.

I feel much pleasure to convey the profound thanks to my friends, well wishers for their active encouragement and inspiration; personal acknowledgements are made to ***Jahid.***

Place: Dhaka

Dated: The June 2017

EFFECT OF ZINC AND COPPER ON THE GROWTH AND YIELD OF TOMATO

ABSTRACT

A pot experiment was carried out at the net house of Soil Science Department of Sher-e-Bangla Agricultural University, Dhaka during the period from October, 2016 to March, 2017 to study the effect of Zinc(Zn) and Copper(Cu) on the growth and yield of tomato. There were six doses of fertilizer in experiment, viz., T_0= Control, T_1= Recommended dose of fertilizer ($N_{160}P_{50}K_{100}S_{20}$)kg/ha , T_2=75% NPKS from inorganic fertilizer and 25% NPKS from cowdung, T_3= Recommended dose of fertilizer with Zn and Cu ($N_{160}P_{50}K_{100}S_{20}+Zn_4+Cu_4$)kg/ha, T_4= Recommended dose of fertilizer with Cu ($N_{160}P_{50}K_{100}S_{20}$ $+Cu_4$)kg/ha, T_5= Recommended dose of fertilizer with Zn ($N_{160}P_{50}K_{100}S_{20}+Zn_4$)kg/ha were used to conduct this experiment. The experiment was laid out in Randomized complete Block Design (RCBD) having one factors and three replications . Data were taken on growth, yield contributing characters, yield and the collected data were statistically analyzed for evaluation of the treatment effects. All the plant parameters were influenced significantly by the application Zn and Cu with other chemical fertilizers. The tallest plant, maximum number of leaves per plant, number of branches per plant, maximum number of flowers cluster per plant number of flowers per plant were produced by recommended dose of fertilizer with Zn and Cu ($N_{160}P_{50}K_{100}S_{20}+Zn_4+Cu_4$)kg/ha**.** The higher number of fruit per plant was observed in **T_3** treatment. The Zinc and Copper of tomato significantly influenced on the yield of fruits per plant. The maximum yield of fruits per plant (347.60 g) was obtained from **T_3** treatment and the minimum yield of fruits per plant (183.73 g) was obtained from control treatment.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agricultural Organization
N	=	Nitrogen
B	=	Boron
et al.	=	And others
TSP	=	Triple Super Phosphate
MOP	=	Muirate of Potash
RCBD	=	Randomized Complete Block Design
DAT	=	Days after Transplanting
ha^{-1}	=	Per hectare
g	=	gram (s)
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
wt	=	Weight
SE	=	Stander Error
^{0}C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance

CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum*) belongs to Solanaceae and is one of the important popular nutritious fruit vegetables crop grown in all over the world including Bangladesh. Usually, it grows well during winter season and cultivated in all parts of the country (Haque *et al.*, 1999) but now it also cultivated in summer season. The origin of tomato is South America (Salunkhe *et al.,* 1987) particularly the Peru-Ecuador-Bolivia areas of Andes and is adapted to a wide variety of climates

Recent statistics showed that tomato was grown in 75602 acre of land and the total production was approximately 4,13,610 metric tons (BBS.2016), which is very low in comparison with that of tomato producing other countries, namely India (15.67 t/ha), Japan (52.82 t/ha) and USA (63.66 t/ha) and suggesting that the yield of tomato in our country is not enough to fulfill our present demand. The low yield of tomato in Bangladesh, however, is not an indication of low yielding ability of this crop, but of the fact that the tomatoes grown here are not always of high yielding cultivars and that the cultural practices commonly used by the growers are not improved.

The importance of agriculture to all human societies is characterized more than ever, with the increasing world population. The first and most important need of every human need to access the food, and food supply for humans is associated with agriculture either directly or indirectly. The world's population will grow to an estimated 8 billion people by 2025 and 9 billion by 2050, and it is widely recognized that global agricultural productivity must increase to feed a rapidly growing world population (FAO/WHO, 2002). Vegetables and fruits are perishables, and in the absence of effective storage, preservation and transportation, the prices are unstable and the availability is uncertain, in addition to the above limitation. The diets of the average Bangladesh household did not show any significant improvement over the last few decades of the century. A challenge for global food and nutrition security is to feed the world population with nourishing food (Quasem *et al*., 2009; Ghaly, 2009). Hence, emphasis should be laid on production of high quality food with the required level of nutrients and proteins (Pijls *et al*., 2009; Ghaly and Alkoaik, 2010). To meet this increasing demand, researchers are trying to develop an efficient and ecofriendly production technology based on the innovative technologies.

The issue of micronutrient deficiency relates to food security (Meenakshi *et al*., 2010; Ghaly and Alkoaik, 2010). Micronutrient deficiencies in human beings, as well as crop plants are difficult to diagnose, and accordingly, the problem is termed as 'hidden hunger' (Stein *et al*., 2008). This hidden hunger may cause nearly 40% reduction in crop productivity, and it is also estimated that it affects more than a half of the global population. Micronutrient deficiency in general refers to Fe, Zn, Se, Mo, Cu, Ca and Mg (Zhao and McGrath, 2009), among them Zinc (Zn) deficiency is more widespread next to Iron, Vitamin A and Iodine. WHO reported that Zn deficiency stands fifth risk factor in causing diseases among children in the developing countries. Based on analysis of diet composition and nutritional needs, it has been estimated that 49 percent of the world's population (equivalent to 3 billion) is at risk of suffering from Zn deficiency. Until the recent times, soil fertilization was the only way to meet the mineral requirement of crop plants. However, several problems exist like need for large quantity of fertilizer, fixation in soil and slow uptake by plants.

Zinc has a specific physiological functions in all living systems, such as i) maintenance of structural and functional integrity of biological membranes, ii) as a cofactor for more than 300 enzymes, iii) detoxification of highly toxic oxygen free radicals iv) contribution to protein synthesis and gene expression under normal and stress conditions etc. Among all metals, Zn is needed by the largest number of proteins, at least 2800 proteins are Zn dependent and make up nearly 10 per cent proteomes in eukaryotes, Zn has a vital role in several body functions such as vision, taste perception, cognition, cell reproduction, growth and immunity, resistance to some infectious diseases such as diarrhoea (Black., 1998) and immunity, (Shankar and Prasad., 1998).

Traces of heavy metals are required for plant metabolism, growth, and development, whereas high concentrations of them are toxic (Clemens, 2006). Heavy metal concentrations in soil range from less than 1 mg/kg to high as 100,000 mg/kg, due to the geological origin of the soil or as a result of human activity (Blaylock and Huang, 2000). Currently, contamination of soil in cultivated fields with toxic heavy metals such as cadmium, copper, nickel and zinc has emerged as a new threat to agriculture (Singh *et al.*, 2007). These metals persist indefinitely in soil thereby posing an ever increasing threat to human health and agriculture, causing carcinogenic and mutagenic effects (Leyval *et al.*, 1995; Hema and Subramani, 2013).

Copper and Zinc are important among the most abundant heavy metals in the agricultural soils. Copper and Zinc are actively involved in the cellular metabolism because both of them, mostly zinc, are present in many proteins (Hall, 2002). Copper and zinc are essential heavy metals (Hojiboland *et al.*, 2006; Clemens, 2006; Singh *et al.*, 2007), however highly toxic and biologically active at high concentration (Kramer et al., 2007). Metal toxicity is an important factor governing germination and growth of plants (Houshmandfar and Moraghebi, 2011). Study on Cu and Zn toxicity on *Phaseolus vulgaris* and Mung bean revealed that seedling growth is significantly affected at high concentrations (Hojiboland *et al.*, 2006). The effects of toxic substances on plants are dependent on the amount of toxic substance taken up from the given environment. Metal toxicity primarily depends on plant species as they exhibit considerable genetic variation in their ability in tolerating amounts and the concentration of specific heavy metals (Vojtechova *et al.*, 1991). However, the combined use of Zn and Cu is not clearly shown by the earlier scientist. Considering the above situation, present experiment was designed with the following objectives:

1. To know the effects of Zn and Cu on the yield of tomato.
2. To know the effect of integrated nutrient management on the growth and yield of tomato.

CHAPTER II

REVIEW OF LITERATURE

Tomato is an important vegetable crop and received much attention of the researchers throughout the world to develop its suitable production technique. Establishment and growth of tomato plants depend on Zn and Cu. Number of researchers has studied the effect of Zn and Cu on the growth and yield of tomato in different countries of the world, but their findings have little relevance to the agro-ecological situation of Bangladesh. However, literature available in this respect at home and abroad has been reviewed here, which will contribute useful information to the present study.

Sommer and Lipman (1926) were the first to prove the essentiality of Zn as a nutrient requirement for higher plants. Plants absorb zinc in the form of Zn^{2+}. The functional role of Zn includes auxins metabolism, nitrogen metabolism, influence on the activities of enzymes (e.g. dehydrogenase and carbonicanhydrase, proteinases and peptidases), cytochrome C synthesis, stabilization of ribosomal fractions and protection of cells against oxidative stress (Tisdale *et al.,* 1997; Obata *et at.*, 1999).

The effects of adding Zn *(5* kg/ha), Cu (3 kg/ha) or FYM (30 t/ha) to the basic N:P:K (222:160:100 kg/ha) treatment as leaf transpiration and chlorophyll content and fruit ascorbic acid and sugar contents were studied by Annanurova *et al.*(1992). The treatment was generally beneficial and the number and mean weight of fruits were increased. Application of NPK alone increased yield/plant by 43.4%, compared to the untreated control. Each nutrient had a positive impact on vegetative growth as well as on yield and yield attributes of tomato.

Yadav *et al.*(2001) conducted a field experiment at Hisar, Haryana, India in 1990and 1991 to study the effect of zinc (0, *5*, 10, *15*, and 20 kg Sulphate /(ha) and boron (0, 1, 2, and 4 kg/ha) on the yield and nutrient content and uptake by tomato plants cv. Pusa-120. All the treatments significantly increased tomato yield. The maximum yield was obtained with 15 kg $ZnSO_4$ and 2 kg B/ha. The highest concentration and uptake of zinc and boron were recorded for 20 kg $ZnSO_4$and 4 kg B/ha.

Patnaik *et al.*(2001) conducted field experiments during 1997-98 in Hyderabad, Andhra Pradesh, India, to determine the effect of Zn and Fe on yield and quality of tomato cv. Marutham. The treatment comprised a control, soil application of 12.5and 25 kg $ZnSO_4$/ha, soil application of 12.5 kg $ZnSO_4$/ha + foliar spray of 0.2%$ZnSO_4$ (thrice at weekly intervals), soil application of 12.5 kg $ZnSO_4$ spray (thrice at weekly intervals), and soil application of 12.5 kg ZnSO4/ha along with sprays of 0.2% $ZnSO_4$ + 0.5% $FeSO_4$. Among the treatments, soil application of 12.5 kg $ZnSO_4$/ha, followed by foliar sprays of 0.2% $ZnSO_4$ and 0.5% $FeSO_4$ thrice at weekly interval resulted in the highest fruit yield of 39.9 t/ha with a maximum yield response of 39%. The Zn and Fe contents in index leaves of tomato were in the range of 18.5-273 mg/kg and 116-160 kg, respectively. The nutrients in index leaves were higher in the treatment where Zn and Fe were applied either through soil or through foliar spray. A similar trend was observed in fruits when Zn and Fe were sprayed along with soil application. In general, Zn and Fe contents were less in fruits (14.1-17.6 mg/ka) compared to leaves (37.2-72.7 mg/kg). The highest uptake of Zn and Fe was recorded with 12.5 kg $ZnS0_4$ soil application along with 0.2% $ZnSO_4$ and 0.5% $FeSO_4$ sprays.

Yadav *et al.* (2001b) conducted a study during 1990 and 1991, in Hisar, Haryana,India, to evaluate the effect of different concentrations of zinc and boron on the vegetative growth, flowering and fruiting of tomato. The treatments comprised five levels of zinc (0, *2.5*, *5.0*, 7.50 and 10.0 ppm) and four levels of boron (0, *0.50,*0.75 and 1.00 ppm) as soil application, as well as 0.5% zinc and 0.3% boron as foliar application. The highest values for secondary branches, leaf area, total chlorophyll content, fresh weight, fruit length, fruit breadth and fruit number were obtained with the application of 7.5 ppm zinc and 1.0 ppm boron.

A short term experiment was conducted by Kaya and Higgs (2001) with tomato cultivars Blizzard, Liberto and Calypso was carried out in a controlled room temperature to investigate the effectiveness of phosphorus (P) and iron (Fe) supplemented in nutrient solution on plant growth at high zinc concentration. Application of supplementary P and Fe resulted a marked increase in both dry weight and chlorophyll concentrations achieving values not significantly different to the control. Application of supplementary P and Fe decreased Zn concentration in the leaves and roots of plants grown at high Zn, but Zn concentrations were still at toxic levels. Phosphorus and Fe concentration in leaves declined to a deficient level in the high Zn treatment, but was markedly increased in the roots. Application of supplementary P and Fe corrected both P and Fe deficiencies in leaves of plants grown at high Zn and reduced root and Fe concentrations.

Dry matter production uptake of NPK nutrients and the residual soil fertility are favorably influenced by NPK combined with boron and zinc (Balasubramaniam *et al*, 1998). Application of soil test based NPK combined with boron (10 kg/ha), Zinc sulphate *(*50 kg/ha) ad composed coir pith (5 t/ha) was reported to give the highest fruit yield of tomato.

The effect of Zn (0.0, 1.0, *2.5.* 5.0 or 10.0 mg/kg soil as zinc sulphate) on the yield and quality of tomato cv. Pusa Ruby was studied in a pot experiment. Application of Zn significantly improved biomass, fruit yield and fruit quality. The highest biomass, fruit yield, total pulp weight, acidity, and lycopene, ascorbic acid, total carotene and water contents were obtained with 5.0 mg Zn/kg soil. Zinc application at 10 mg/kg tended to have an adverse effect on fruit quality. The contents of P. Fe, Mn and Cu generally decreased with and increase in Zn concentration. The Zn content of leaves was highest at the highest rate of Zn (Dube *et al.*, 2003).

In micronutrient malnutrition, zinc is second to iron in terms of importance. Over the past many years, large efforts have been made to seek for breeding options to bio fertility major staple crops with Zn, Fe, and vitamin A (Welch and Graham, 2004). Biofertilization of food crops with *Zn* by either breeding for higher uptake efficiency or by fertilization can be an effective strategy to address widespread dietary deficiencies in human population (Graham *et at.,* 2001).Plants emerged from seed with low concentrations of Zn could be highly sensitive to biotic and abiotic stresses (Obata *et* at., 1999). Zinc enriched seeds can perform better with respect to seed germination, seedling health growth and finally yield advantage (Cakmak *et* at., 1996)

A study was conducted by Adiloglu *et al.* (2005) to determine the effect of increasing nitrogen fertilizer doses on the zinc uptake of tomato *(Solanum lycopersicum L.)* in soils of different physical and chemical lproperties. Results showed that the dry matter content of the tomato plant increased with increasing doses of N and Zn doses. The N and Zn contents of the tomato plants increased with increasing rates of N and Zn, respectively.

Zinc concentration is higher in legume crops than in cereals. Its concentrations were found to be on an average 18, 30, 39 and 55 g in grain of corn, rice, drybean and soybean (Frageria, 2007). High grain-Zn concentration is considered a desirable quality (Cakmak *et* al, 1996; Graham *et al*, 1992). High Zn-seed concentrations are also a desirable trait to ensure seedling vigor and grain yield of the next crop when replanted on Zn deficient soil (Graham *et al.*, 1992).

Hossain *et al.* (2008) conducted experiments over 3 years to find out an optimum rate of application for the maize-mungbean-rice cropping system in a calcareous soil of Bangladesh. Zinc application was made at 0, 2 and 4 kg/ha for maize (cv. Pacific 984, Thai hybrid) and at 0. 1 and 2 kg ha^{-1} for rice (cv. BRRIdhan-33), with no Zn application for mungbean (cv. BARI mung-5). Effect of Zn was evaluated in terms of yield and mineral nutrient contents (N, P. S and Zn). All the three crops responded significantly to Zn application. The optimum rate of Zn for the maize-mungbean-rice cropping system was found to be 4-0-2 kg/ha for the first year and 2-0-2 kg/ha" for subsequent years particularly when mungbean residue was removed, and such rates of mungbean residue incorporation.

In the present study, an attempt was made by Khanm *et al*. (2017) to study the effect of nano zinc oxide particle (ZnO NPS) for improving yield and Zn content in tomato plant. Initially, seed priming concentration was standardized in vitro using ZnO NPS (400ppm) and granular zinc sulphate ($ZnSO_4$) (800ppm). Further, standardized seed priming concentrations with different combinations of treatment such as seed priming, seed priming+ foliar spray and flour spray was studied under field condition to evaluate their effect on biomass and Zn accumulation The obtained results based on the physiological and yield parameters showed that the usage of ZnO NPS fertilizers through any of the methods of application has a significant positive effect, compared to zinc sulphate. ICP-OES analysis of plant digested material revealed that the uptake of ZnO NPS is higher than the granular $ZnSO_4$. The present study addresses the potential of nano scale particles of plant system, opening an avenue for its potential use as future “nano fertilizers”. This nanotechnology is one of the technologies where, a lot of scope exists to improve the plant nutrition.

Elizabath *et al.* (2017) concluded that the best yield attributes in namely, plant height (cm) (91.24 cm), number of leaves/plant (12.47), petiole length/plant (cm) (13.38cm), and leaf area (cm^2) (75.73cm^2), root diameter (cm) (3.53cm), root length (cm) (19.75cm), root yield/treatment (kg) (72.33kg) and root yield/hectare (t/ha) (29.41 t/ha) in T8 (Z2F1: ZnO NPS @100ppm + FeO NPS @50ppm), and also concluded that the best cost benefit ratio 2.02, was obtained T8 (Z2F1: ZnO NPS @ 100ppm + FeO NPS @ 50ppm).

Ullah *et al.* (2015) was carried out an experiment at Agriculture Research Institute (ARI) Tarnab Peshawar, during 2012 to study the "Growth and yield of tomato *(Lycopersicon esculentum* L.) cv 'Rio Grand as influenced by different levels of zinc and boron as foliar application'. Four levels of zinc (0, 0.2, 0.4 and 0.6%) and four levels of boron (0, 0.05, 0.10 and 0.15%) were applied as foliar spray. 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).

Ali *et al.* (2015) conducted an experiment with BARI hybrid tomato 4, cultivated in summer season of Bangladesh,where foliar application of zinc and boron [T0: control; T1: 25-ppm $ZnSO_4$ (Zinc Sulphate); T2: 25-ppm H_3BO_3 (Boric Acid) and T3: 12.5-ppm $ZnSO_4$ + 12.5-ppm H_3BO_3] was done. 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 maximum foliar application of 12.5-ppm ZnSO4 + 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 Zn and boron was more effective than the individual application of Zn or boron on growth and yield for summer season tomato (BARI hybrid tomato 4).

Shams and Morsy (2014) conducted an experiment with two successive winter seasons of 2012/2013 and 2013/2014 in the farm of the Faculty of Agriculture, Moshtohor, Benha University, Egypt, to explore the effects of treating the plastic tunnels with ZnO nanoparticles on the growth parameters, yield and its quality of tomato (*Lycopersicon esculentum* Mill cv. Super Strain B). It also investigates the effects of using the foliar application of chitosan nanoparticles applied at 0.5 and 1% versus the commercial chitosan applied at the same rates on the growth parameters and the yield of tomatoes and whether these treatments could be positively/negatively affected by treating the plastic tunnels with ZnO nanoparticles. Results revealed that the tomato plants grown under nano-composite covering (PE with nano-ZnO) gave rise to vigor growth, higher yield and fruit quality compared with the tomato plants under low plastic tunnel (PE without nano-ZnO). Chitosan nanoparticles (0.5 or 1 %) increased the plant growth (plant height, fresh, dry weight and leave area), early and total yield per plant and per feddan and average fruit weight beside of improving the quality of fruits (vitamin C, acidity and total sugars) than all other treatments. Thus, using chitosan nano particles (0.5 or 1 %) under nano-composite covering (PE with nano-ZnO) is the recommended practice to attain good growth parameters and achieve early and high total yield with better quality of tomato fruits. However, the low concentration of chitosan nano-particles achieves the highest return economist in this case.

Gurmani *et al*. (2012) conducted a glasshouse pot experiment and effect of soil applied Zinc (@ 0, 5, 10 & 15 mg kg-1) on the growth, yield and biochemical attributes were studied of two tomato cultivars; VCT-1 and Riogrande. 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 this study suggest 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.

Salam *et al*. (2011) conducted an experiment at the Vegetable Research Farm of the Horticulture Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur to investigate the effect of boron, zinc, and cowdung on quality of tomato. The results reflected that the highest pulp weight (90.24%), dry matter content (5.82%), ascorbic acid (11.2 mg/100g). lycopene content (147 µg/100g), chlorophyll-a (42.0 µg/l00g), chlorophyll-b (61.0 µg/100g), boron content (36 µg/g), zinc content (51 µg /g), marketable fruits at 30 days after storage (74%) and shelf life (17 days) were recorded with the combination of 2.5 kg B/ha + 6 kg Zn/ha, and 20 t/ha cowdung.

The influence of the endogenous micronutrient chelator, nicotianamine (NA), and of Cu nutrition on the distribution of Cu, Fe, Mn, Zn, and Na was investigated by Pich and Scholz (1996) in eight different shoot organs, roots, and in xylem exudates of the NA-containing tomato wild type *Lycopersicon esculentum* Mill. cv. Bonner Beste and its NA-less mutant *chloronerva.* Contrary to the other heavy metals, copper transport in the xylem was inefficient in the mutant and was enhanced by an application of NA to the roots or leaves in proportion to the applied NA concentration. Also, with NA application, the Cu concentration in mutant roots decreased significantly, and increased in the shoot. Fe and Mn transport in the xylem was greater in the mutant than in the wild type, and was decreasedin the mutant by the application of NA to the leaves. Zn transport in the xylem was the same in both genotypes and was unaffected by NA application. After application of NA to leaves and roots of the mutant it was possible to detect NA in the xylem exudate (up to 2nmol NA(g"1 root FWh"1). High Cu supply (3 *ftfA)* resulted in higher Cu and Mn concentrations in all organs of the wild type as compared to mutant organs, but Fe concentrations were not influenced. Under high Cu supply (3//M) the NA concentrations of roots and the three youngest leaves of the wild type were higher than under normal Cu supply (0.3 //M). The highest concentrations were found in the shoot apex under both Cu conditions (up to 361 nmol NAg"1 FW). It is concluded from our experiments and from the high stability constant of the NA-Cu-complex (log *K*= 18.6) that NA is involved in Cu translocation whereas for the translocation of Fe, Mn, and Zn, NA is not essential.

Investigations of tomato were carried out under greenhouse and field conditions. The aim was to determine the extent to which greenhouse conditions influence the chemical composition of tomato fruits. Plants grown under field conditions were used as the control. Tomato trials were performed during different periods. Greenhouse trials were carried out in the winter and the spring period (January-June), and field trials in the spring and the summer period (May- September). Zinc (Zn), iron (Fe) and copper (Cu) content were established in ripe tomato fruits. Greenhouse conditions were found to effect zinc and iron content in tomato, whereas copper content was unaltered (Bjelić *et al*, 2005).

Ashagre *et al.* (2013) conducted to investigation to know the effect of copper and zinc on germination, phytotoxicity, seedling vigor and tolerance. The laboratory experiment was undertaken on tomato (cultivar Roma VF) at Ambo University, Ethiopia. Copper and zinc in seven levels each (0, 100, 200, 300, 400, 500 and 600 ppm), were arranged in factorial CRD with four replications. Copper and zinc concentrations significantly ($p<0.05$) decreased germination percentage and rate, shoot and root lengths, seedling vigor, and tolerance. However, toxicity percentage to shoot and root increased significantly ($p<0.05$) with increasing metals concentrations. Maximum germination, shoot and root lengths, tolerance, and seedling vigor were obtained with controls. Minimum value for the germination percentage (76.6%), germination rate (4.6plants/day), shoot and root lengths, tolerance and vigor were expressed at 600ppm - zinc; however, copper ≥300ppm induced total failure on tomato seeds germination. The highest toxicity to shoot (92.3%) and root (93.4%) appeared at 600ppm zinc, whereas ≥300 ppm copper caused 100% toxicity on shoot and root. 100ppm, copper was toxic to shoot (61%) and roots (85%), while zinc showed toxicity of 68% of shoot and 66% of root toxicity. Hence, other than 100ppm, copper is more toxic than zinc for germination and seedling growth of Roma VF.

In this work, the effect of excess copper (Cu) on tomato plants grown in hydroponic solutions for up to 15 days was studied by Martins and Mourato (2006) . The solutions contained different Cu concentrations ranging from 0.05, 0.15, 0.20, and 0.35 mM Cu. Dry mass, root length, and foliar area decreased with time and Cu solution concentration. Copper accumulated more heavily in roots than in leaves. Mineral uptake was affected by increasing Cu concentrations in solution with calcium (Ca), iron (Fe), and zinc (Zn) contents in leaves decreasing. Except for Ca, the concentrations of these elements in the roots also decreased, which indicated that root uptake was affected and the translocation to upper plant parts was disrupted. Iron leaf deficiency was the probable cause of the observed chlorosis and decrease in chlorophyll levels. The activities of three enzymes studied in leaves (guaiacol peroxidases (GPOD), catalase (CAT), and polyphenol oxidase (PPO)) increased transiently, probably as an early response mechanism against Cu induced oxidative stress. At higher Cu concentrations, this defense mechanism broke down and the activities of the enzymes decreased accordingly.

Mediouni *et al.* (2006) studied cadmium (Cd) and copper (Cu) toxicity in tomato, their accumulation in plant organs and their ability to induce phytochelatin synthesis. The seedlings were cultivated in nutrient solution supplemented with increased concentrations of $CdCl_2$ or $CuSO_4$ from 0 to 50 μM. After 7 days of treatment, plants were harvested and the dry weight, the amount of thiobarbituric acid-reactive substances (TBARS), Cd and Cu contents and SH groups rich peptides were determined. We found that Cd and Cu decrease tomato growth, notably at high Cu levels. Cd and Cu concentrations in plant organs increased with applied amounts. Cd and Cu concentrations were the highest in roots. The amount of thiobarbituric acid-reactive substances, that estimate the lipid peroxidation, was increased with heavy metal exposure and was, mainly, higher in roots with Cu treatment.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods that were used in carrying out the experiment. It includes a short description of location of the experimental plot, characteristics of soil, climate and materials used for the experiment. The details of the experiment are described below.

3.1 Location of the experiment

The experiment of pot was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka from October 2016 to March, 2017 to effect of Zn and Cu on the growth and yield of tomato which is shown in Appendix I.

3.2 Climate of the experimental area

The area is characterized by hot and humid climate. The average rainfall of the locality of the experimental area is 209.06 mm, the minimum and maximum temperature is 11.10 °C and 34.80ºC respectively. The average relative humidity was 75.8 % during October 2016 to March, 2017.

3.3. Soil of the experimental

Initial soil samples from 0-15 cm depth were collected from experimental field. The collected samples were analyzed at Soil Resources Development Institute (SRDI), Dhaka, Bangladesh. The physio-chemical properties of the soil are presented in Appendix II. The soils of the experiment belonged to he agro-ecological zone of Madhupur Tract (AEZ-28), which is shown in Appendix I.

3.4 Plant materials used

In this research work, the seeds of one tomato varieties were used as planting materials. The tomato varieties used in the experiments were BARI Tomato 2. Variety is semi-indeterminate type. BARI Tomato-2 was collected from the Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI) at Joydebpur, Gazipur.

3.5. Raising of seedlings

Tomato seedlings were raised in seedbed of 2 m x 1m size. A distance of 50 cm was maintained between the beds. The soil was well prepared and converted into loose friable and dried mass by spading. All weeds and stubbles were removed. Four gram of seeds was sown on each seedbed. 50gm furadan was applied around each seedbed as precautionary measure against fungus, ants, worm and other harmful insects. The emergence of the seedlings took place with 6 to 8 days after sowing. Diathane M-45 was sprayed in the seedbeds @ 2 gm/l, to protect the seedlings from damping off and other diseases. Weeding, Mulching and Irrigation were done as and when required.

3.6 Treatments and layout of the experiment

There were six treatment combinations used in experiment. The treatments were as follows:

a) T_0= Control

b) T_1= Recommended dose of NPKS fertilizers ($N_{160}P_{50}K_{100}S_{20}$)kg/ha

c) T_2=75% NPKS from inorganic fertilizer and 25% NPKS from cowdung.

d) T_3= Recommended dose of NPKS+Zn+Cu ($N_{160}P_{50}K_{100}S_{20}Zn_4Cu_4$)kg/ha.

e) T_4= Recommended dose of NPKS +Cu ($N_{160}P_{50}K_{100}S_{20}Cu_4$)kg/ha.

f) T_5= Recommended dose of NPKS+Zn ($N_{160}P_{50}K_{100}S_{20}Zn_4$)kg/ha

3.7 Design and layout of the experiment

The experiment was carried out in pot culture based. The pot culture experiment was laid out in a Randomized Complete Block Design with three replications.

3.8 Cultivation procedure

3.8.1 Pot preparation

Muddy pots were used. At first the pots were sun dried. Twelve kg silty clay loam soil was taken in 18 pots and treatment wise cowdung and fertilizers were mixed in pot soils at 7 days before transplanting. Weeds and stubbles were removed from the soil. The pH of the soil was 6.0 to 6.4.

3.8.2. Manure and fertilizers and its methods of application

Urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, Zn ($ZnSO_4$) and Cu ($CuSO_4$) fertilizers were calculated as per treatment and the weight of soil taken in the pots. Triple super phosphate (TSP), muriate of potash (MoP), gypsum, Zn ($ZnSO_4$) and Cu ($CuSO_4$) fertilizers were applied during pot preparation. Treatment wise required amount of cowdung was applied in treatment T_2 during pot preparation. Urea was applied in two equal splits at 15 and 35 days after transplanting

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 pots in the afternoon.

3.8.4 Intercultural operations

After transplanting the seedlings, various kinds of intercultural operations were accomplished for better growth and development of the plants, which are as follows.

a) Weeding and Mulching

Weeding and Mulching were accomplished as and whenever necessary to keep the crop free from weeds, for better soil aeration and to break the crust. It also helped in soil moisture conservation.

b) Staking and Pruning

When the plants were well established, staking was given to each plant by Daincha (*Sesbania* sp.) and bamboo sticks to keep them erect. Within a few days of staking, as the plants grew up, the plants were given a uniform moderate pruning.

c) Irrigation

Light irrigation was provided immediately after transplanting the seedlings and it was continued till the seedlings established in the field. Thereafter irrigation was provided.

d)Plant protection

Insect pests: Malathion 57 EC was applied & 2 ml 1^{-1} against the insect pests like cut worm, leaf hopper, fruit borer and others. The insecticide application was made fortnightly for a week after transplanting to a week before first harvesting. Furadan 10 G was also applied during final land preparation as soil insecticide.

Diseases: During foggy weather precautionary measured against disease infection of Winter tomato was taken by spraying Diathane M-45 fortnightly & 2 gm l^{-1}, at the early vegetative stage. Ridomil gold was also applied @ 2 gm 1^{-1} against early blight disease of tomato.

3.9 Harvesting

Fruits were harvested at 5-day intervals during early ripe stage when they attained slightly red color. Harvesting was started from 25 January, 2017 and was continued up to 10 March 2017.

3.10 Data collection

Ten 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 (cm)

Plant height was measured from sample plants in centimeter from the ground level to the tip of the longest stem and mean value was calculated.

3.10.2 Number of leaves per plant

Number of leaves per plant was recorded by the following formula :

Number of leaves per plant =

$$\frac{\text{Total number of leaves from ten sample plants}}{10}$$

3.10.3 Number of branches per plant

Number of primary branches per plant was measured by the following formula:

Number of branches per plant =

$$\frac{\text{Total number ofprimary branches from ten sample plants}}{10}$$

3.10.4 Number of flowers cluster per plant

Total number of flower clusters was counted from selected flowers cluster of sample plant and was calculated by the following formula:

$$\text{Number of cluster per plant} = \frac{\text{Total number of cluster from ten sample plants}}{\text{Total number of flowers clusters from ten sample plants}}$$

3.10.5 Number of flowers per plant

Total number of flowers was counted from selected flowers of sample plant and was calculated by the following formula:

Number of flowers per plant = $\frac{\text{Total number of flowers from ten sample plants}}{\text{Ten sample plants}}$

3.10.6 Number of fruits per plant

It was recorded by the following formula

Number of fruits per plant $= \frac{\text{Total number of fruits from ten sample plants}}{10}$

3.10.7 Weight of fruits per plant (kg)

A per scale balance was used to take the weight of fruits per plant. It was measured by total fruit of plant separately during the period from fruit to final harvest and was recorded in kilogram (kg).

3. 10. 8 Dry weight fruit (g)

Five fruit were collected randomly from each plot and dried separately for 48 hours in an electric oven set at 65 degree C .The dry weight of the samples was taken using a sensitive digital electric balance. The mean weight was calculated to have individual fruit weight and expressed in g.

3.11 Statistical analysis

The recorded data on various parameters were statistically analyzed by using MSTAT-C statistical package. The mean for all the treatments was calculated and analysis of variance for all the characters was performed by F-test. Difference between treatment means were determined by Duncan`s new Multiple Range Test (DMRT) according to Gomez and Gomes, (1984).

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises the presentation and discussion of the results from the experiment. The experiment was conducted to determine the effect of Zn and Cu on the growth and yield of tomato. Some of the data have been presented and expressed in table (s) and others in figures for ease of discussion, comparison and understanding. A summary of all the parameters have been shown in possible interpretation wherever necessary have given under the following headings.

4.1 Plant height (cm)

Plant height is one of the important parameter, which is positively correlated with the yield of tomato (Taleb, 1994). Plant height was recorded at harvest. Plant height due to the influence of different level of Zinc and copper was significant. The highest plant height (34.67 cm) was produced from T_3 (Recommended dose of NPKS+Zn+Cu) treatment, which was statistically similar with T_1 (Recommended dose of NPKS fertilizers) and T_2 (75% NPKS from inorganic fertilizer and 25% NPKS from cowdung). However, the lowest plant height (26.33cm) was obtained from T_0 (control) treatment, which was statistically similar with T_4 (Recommended dose of NPKS fertilizers+Cu) and T_5 (Recommended dose of NPKS fertilizers+Cu) (Table 1). Mondal *et al.* (1992) found that plant height of tomato was increased up to the highest level of zinc.

Table 1. Effect of Zinc and Copper on the plant height, number of leaves per plant and number of branch per plant of tomato

Treatment	Plant height (cm)	Number of leaves per plant	Number of branch per plant
T_0	26.33 b	39.00 c	4.00
T_1	32.00 a	53.00 b	5.00
T_2	33.67 a	49.33 b	5.00
T_3	34.67 a	59.33 a	5.33
T_4	28.33 b	42.67 c	5.00
T_5	28.33 b	53.33 b	4.00
SE(±)	0.92	0.50	NS
CV(%)	5.20	18.41	NS

4.2 Number of leaves per plant

A good number of leaves indicated better growth and development of crop. It is also possibly related to the yield of tomato. The greater number of leaf, the greater the photosynthetic area which may result higher fruit yield. Number of leaves per plant due to the influence of Zinc and copper was significant. The T_3 treatment had the highest number of leaves per plant (59.33). However, the lowest number of leaves per plant (39.00) was obtained from the T_0 treatment (Table 1).

4.3 Number of branches per plant

The number of branches per plant was not significantly influenced by the application of different fertilizer treatment in combination with and without Zn and Cu fertilizer. The T_3 had the highest number of branches per plant (5.33) and the lowest number of branches per plant (4.00) was obtained from the T_0 and T_5 treatment (Table 1). Similar result was reported by Yadav *et al.* (2001b).

4.4 Number of flowers cluster per plant

There was a significant difference among the Zinc and copper fertilizer applied and other fertilizer treatments in the number of flowers cluster per plant. As evident from Table 2, the maximum number of flowers cluster per plant (8.00) was produced in T_3, which was statistically similar to T_4 (Recommended dose of NPKS +Cu) treatment. The minimum number of flowers cluster per plant (5.00) was produced in T_0 (control) and T_5 treatment.

Table 2. Effect of Zinc and Copper on the number of flower Clusters per plant, number of flowers per plant and number of fruits per plant of tomato

Treatment	Number of flower Clusters per plant	Number of flowers per plant	Number of fruits per plant
T_0	5.00 c	31.00 c	9.00 d
T_1	6.00 b	38.33 b	18.33 bc
T_2	6.00 b	36.67 b	18.33 bc
T_3	8.00 a	42.00 a	23.00 a
T_4	7.33 a	32.33 c	16.00 c
T_5	5.00 c	33.00 c	20.67 ab
SE(±)	0.76	1.06	1.13
CV(%)	21.29	5.18	11.18

4.5 Number of flowers per plant

There was a significant difference among the fertilizer treatments with and without Zinc and copper fertilizer in the number of flowers per plant (Table 2). The maximum number of flowers per plant (42.00) was produced in T_3 treatment where recommended dose of NPK fertilizers plus Zn and Cu fertilizers were applied. The minimum number of flowers per cluster (31.00) was produced in T_0 treatment, which was statistically similar with T_4 and T_5. Zinc and copper have effect on many functions of the plant such as hormone movement, flowering and fruiting process, pollen germination that leads to maximum flowering with optimum doses.

4.6 Number of fruits per plant

Number of fruit per plant due to the influence of nitrogen, phosphorus, potassium, Zinc and copper fertilizers was significantly influenced (Table 2). The highest number of fruit per plant (23.00) was obtained from T_3 treatment and the lowest number of fruit per plant (9.00) was obtained from the T_0 treatment. It was observed that the higher application of Zn increased the number of fruits per plant. Similar result was reported by Yadav *et al.* (2001b)

4.7 Yield of fruits (g) per plant

The yield of fruits per plant was significantly influenced affected by manure and fertilizers with and without Zinc and copper fertilizer (Fig 1.). The maximum yield of fruits per plant (347.60 g) was obtained from T_3 treatment and the minimum yield of fruits per plant (183.73 g) was obtained from T_0 treatment. The highest fruit yield was obtained with 5.0 mg Zn/kg soil was reported Dube *et al.*,2003.

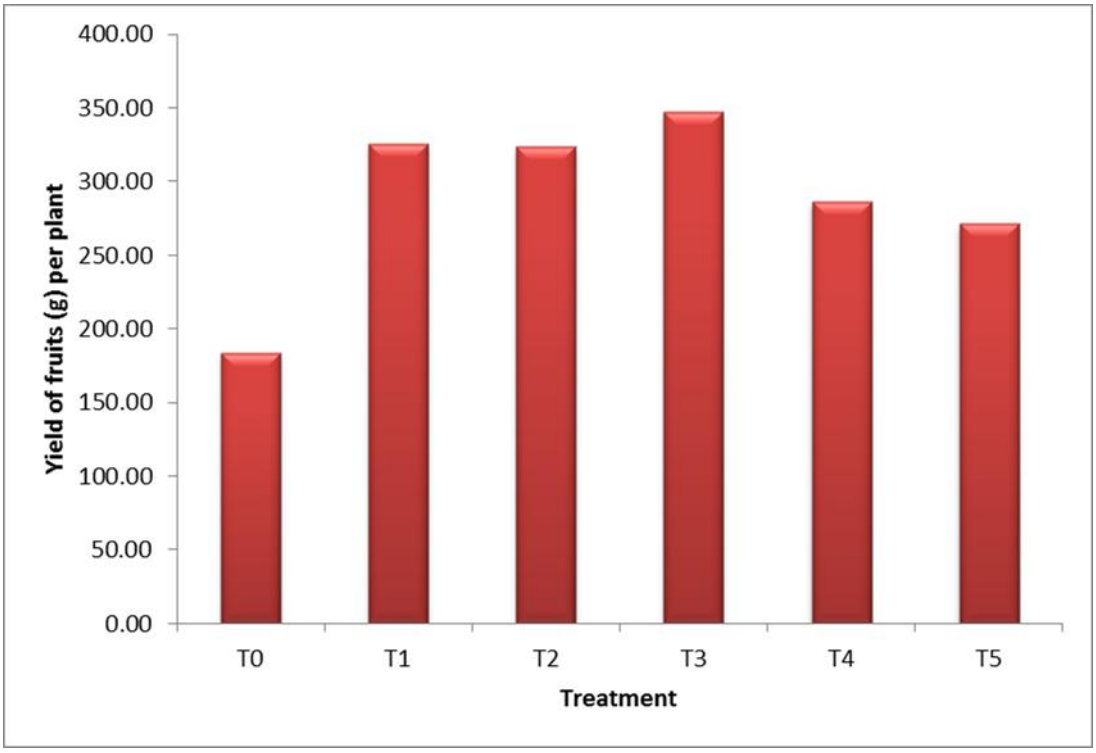


Fig. 1. Effect of Zinc and Copper on yield of fruits (g) per plant of tomato

4.8 Fruit dry weight

The dry weight of tomato fruit varied significantly due to the application of different levels of manure and fertilizer with and without Zinc and copper fertilizer. The highest fruit dry weight of fruit (0.07 g) was obtained from T_3, where recommended dose of NPKS plus Zn and Cu fertilizers were applied, while (T_0) gave the lowest (0.03 g) yield.

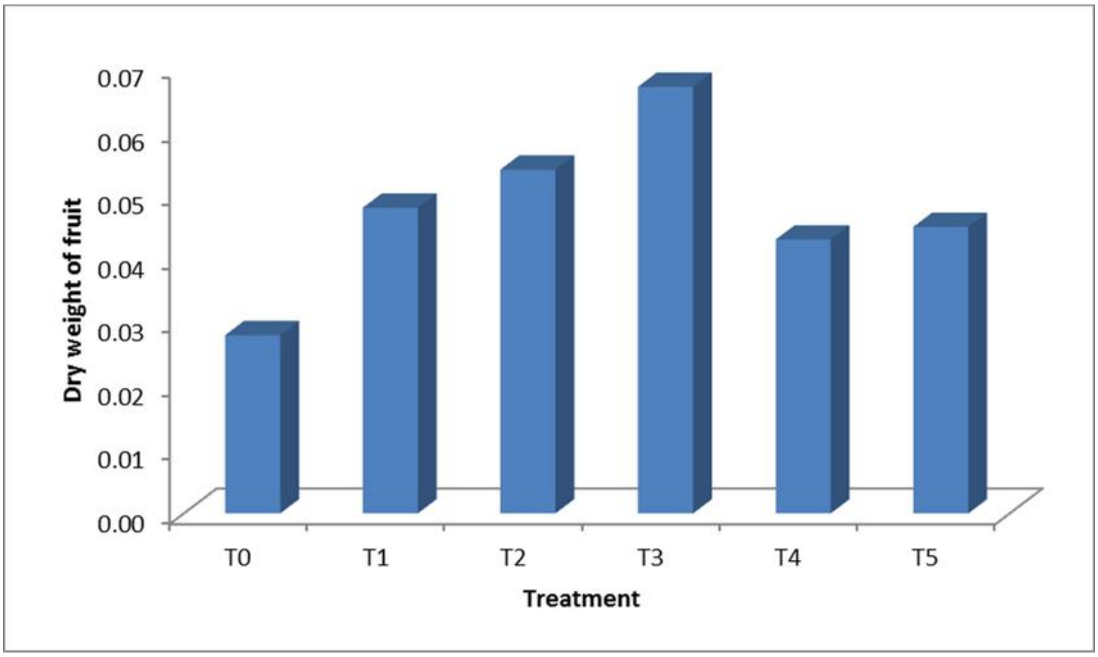


Fig. 2. Effect of Zinc and Copper on dry weight of fruits of tomato

CHAPTER V

SUMMARY AND CONCLUSION

The experiment of pots was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka from October 2016 to March, 2017 to know the effect of Zinc(Zn) and Copper(Cu) combination with other fertilizers on the growth and yield of tomato.There were six treatments used in experiment viz., T_0= Control, T_1= Recommended dose of fertilizers ($N_{160}P_{50}K_{100}S_{20}$) kg/ha , T_2=75% NPKS from inorganic fertilizer and 25% NPKS from cowdung, T_3= Recommended dose of fertilizer with Zn and Cu ($N_{160}P_{50}K_{100}S_{20}$+$Zn_4$+$Cu_4$)kg/ha, T_4= Recommended dose of fertilizer with Cu ($N_{160}P_{50}K_{100}S_{20}$ +Cu_4)kg/ha, T_5= Recommended dose of fertilizer with Zn ($N_{160}P_{50}K_{100}S_{20}$+$Zn_4$)kg/ha were used to conduct this experiment. The experiment was laid out in Randomized complete Block Design (RCBD) having one factors and replicated three times. Data were taken on growth, yield contributing characters, yield and the collected data were statistically analyzed for evaluation of the treatment effects. Plant height due to the influence of different fertilizer treatments with and without Zinc and copper was significantly different. The highest plant height (34.67 cm) was produced from T_3 treatment (Recommended dose of NPKS+Zn+Cu). Number of leaves per plant due to the influence of treatments with and without Zinc and Copper was significant. T_3 treatment had the highest number of leaves per plant (59.33). The number of branches per plant was not significantly influenced by the application of different fertilizer treatment in combination with and without Zn and Cu fertilizer. T_3 treatment had the highest number of branches per plant (5.33). The maximum number of flowers cluster per plant (8.00) was produced in T_3, where recommended dose of NPKS plus Zn and Cu fertilizers were applied. The number of flowers per plant was significantly influence with and without Zn and Cu fertilizers. There was a significant difference among the Zinc and copper fertilizer in the number of flowers per plant. The maximum number of flowers per plant (42.00) was produced in T_3 treatment. Number of fruit per plant due to the influence of different fertilizer treatments with and without Zinc and copper was significant. The highest number of fruit per plant (23.00) was obtained from T_3 treatment. The maximum yield of fruits per plant (347.60 g) was obtained from T_3 treatment and the minimum yield of fruits per plant (183.73 g) was obtained from T_0 treatment. The dry weight of fruit tomato varied significantly due to the application of different levels of with and without Zn and Cu fertilizer. The highest fruit dry weight (0.07 g) was obtained from T_3.

From the present study, the following conclusion has been undertaken.

• The combined effect of recommended dose of NPKS+Zn+Cu enhanced the yield and yield attributes of tomato

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

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.

2. Another level of zinc and copper may be included for drawing conclusion.

REFERENCES

Adiloglu, S., Saglam. M.T. and Dilung, S.K. (2005). The effect of increasing nitrogen doses on the zinc content of tomato plant in the soils of different properties. *Pak J. Biol. Sci.*, **8**(60): 905-909.

Ali, M. R., Mehraj, H. and Jamal Uddin, A. F. M. (2015). Effects of foliar application of zinc and boron on growth and yield of summer tomato. *J. Biosci. and Agric. Res.,* **06**(01): 512-517.

Annanurova, M. A., Rozyeva, M. T., Tailakov and Slovinskaya, L. P. (1992).Effect of fertilizers on some physiological process and fruit quality in tomatoes. Ivz. Akad. Nauk Turkm. SSR, Ser . Biol. Nauk, **3** :49-53.[cited from Hort. Abst., **64** (10):7976

Ashagre, H., Almaw, D. and Feyisa, T. (2013). Effect of copper and zinc on seed germination, phytotoxicity, tolerance and seedling vigor of tomato (*Lycopersicon esculentum* L. cultivar Roma VF). *Int. J. Agric. Sci. Res*. **2**(11), : 312-317.

Balasubramaniam, S. P., Abhor and T. Sharma, N. K., (2001). Effect of Zinc and Boron application on yield, concentration and their uptake by tomato (*Solanum lycopersicum L.),* Haryana **30** (3/4): 251-253.

BBS (Bangladesh Bureau of Statistics). (2016). Yearbook of Agricultural Statistics of Bangladesh, Statistics Division, Ministry of Planning, Govt. of the Peoples Republic of Bangladesh, p. 298.

Bjelić, V., Moravčević, D. and Beatović, D.(2005). Effect of greenhouse conditions on Zn, Fe and Cu content in tomato fruits. *J. Agril. Sci.*. **50** (2) : 101-105.

Black, R. E.(1998), Therapeutic and preventive effects of zinc on serious childhood infectious diseases in developing countries. *Am. J.Clin. Nutr*., **68**: 476–479.

Blaylock MJ, Huang JW (2000). Phytoextraction of metals, In: Raskin I, and Ensley BD (Ed.)

Cakmak, I., Tonin, B., Erenoglu, B., Kalayci, M. A., Yilmaz, H. And Braun, H. J .(1996). Zinc deficiency in soils and plants in turkey and plant mechanism involved in zinc deficiency. *Turk. j. agric. For*.,**20** (Special issue): 13-23.

Cakmak, I., Toum, A., Millet, E., Feldman, M., Fahima, T., Korol, A. B., Nevo, F., Braun, H. J. and Okan, H. (2004).Triticwn dicoccoides: An important genetic resource for increasing Zn and Fe concentration in modern cultivated wheat. *Soil Sci. Plant Nutr*.,**50**:1047-1054.

Clemens, S. (2006). Toxic Metal Accumulation: Responses to exposure and mechanisms of tolerance in plants. Biochemistry, 88: 1707-1719.

Dube, B. K., Pratima-sinha, Chatterjee, C. (2003).Effects of zinc on the yield and quality of tomato. *Indian J. Hort.* **60**(l): 59-63.

Elizabath, A. Bahadur, V., Misra, P. Prasad, V. M. and Thomas, T. 2017. Effect of different concentrations of iron oxide and zinc oxide nanoparticles on growth and yield of carrot (*Daucus carota* L.). *J.Pharmacogn.phytochem*.**6**(4): 1266-1269.

FAO/WHO, (2002), Human vitamin and mineral requirements - Report of a joint FAO/WHO expert consultation - Bangkok, Thailand, FAO, Rome. Chapter 16. Zinc, 257-270.

Frageria, N. K.(2007). Zinc uptake and use efficiency in food crops. In Con. Proc.: Zinc Crops 2007: Improving Crop Production and Human health, Istanbul, Turkey.

Ghaly, A. E. & Alkoaik, F. N. (2010), Extraction of protein from common plant leaves for use as human food. *Am. J. Appl. Sci.*, **7**: 331-342.

Ghaly, A. E.(2009), The black cutworm as a potential human food. *Am. J. Biochem. and Biotech*.,**5**:210- 220.

Gomez. K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research (2nd Edn.). John Willey and Sons, Singapore, pp. 28-92.

Graham, R. D., Ascher, J. S. and Hynes, S. C.(1992). Selection in efficient cereal genotypes for soils of low zinc status. Plant and Soil.**146**: 241-250.

Graham. R. D., Welch. R. M. and Bouis, H. E.(2001). Addressing nutrient malnutrition through enhancing the nutritional quality of staple foods: principles, perspectives and knowledge gaps. *Adv. Agron***.** **70**:77-142.

Gurmani, A.R., J.U. Din, S.U. Khan, R. Andaleep, K. Waseem, A. Khan and Hadyat-Ullah,(2012). Soil Application of zinc improves growth and yield of tomato. *Int. J. Agric. Biol.*, **14**: 91–96.

Hall JL (2002). Cellular mechanisms for heavy metal detoxification and tolerance. *J. Exp. Bot.*, **53**: 1-11.

Haque, M. S., Islam, M. T. and Rahman, M. (1999). Studies on the presentation of semi-concentrated tomato juice. *Bangladesh J. Agril. Sci.,* **26** (1): 153-155.

Hema C, Subramani A (2013). Phyto toxic effect of copper and chromium on seed germination percentage of *Vigna radiata*.L. Int. J. Cur. Res. Rev., **5**(5):95-100.

Hojiboland R, Niknam V, Ebrahim-Zadeh H, Mozafari A (2006). Uptake, transport and chelation of Cu and Zn at toxic levels in tolerant and sensitive species from North West of Iran. *J. Sci.,* **17**: 203-214.

Hojiboland R, Niknam V, Ebrahim-Zadeh H, Mozafari A (2006). Uptake, transport and chelation of Cu and Zn at toxic levels in tolerant and sensitive species from North West of Iran. *J. Sci.,* **17**: 203-214.

Hossain, M. A., Jahiruddin.M., M. R., Islam, and Mian, M. H.(2008). The requirement of zinc for improvement of crop yield and mineral nutrition in the maize mungbean rice system. Plant and soil. **306** (1/2): 13-22.

Houshmandfar A, Moraghebi F (2011). Effect of mixed cadmium, copper, nickel and zinc on seed germination and seedling growth of safflower. *Afri. J. Agric. Res.*, **6**(5): 1182-1187.

Ilyas,M. Ahmad, M, Umar, M., Mukhtar, S. and Farooq, S. Growth and Yield of Tomato *(Lycopersicon esculentum* L.) as Influenced by Different Levels of Zinc and Boron as Foliar Application. *American-Eurasian J. Agric. and Environ. Sci*., **15** (12): 2495-2498.

Kaya, C., and Higgs, D., (2001). Growth enhancement by supplementary phosphorus and iron in tomato cultivars grown hydroponically at high zinc. *J. Plant Nutr.*, **24** (12): 1861-1870.

Khanm, H. Vaishnavi. B. A, Namratha. M. R and Shankar. A. G. (2017). Nano zinc oxide boosting growth and yield in tomato: the rise of “nano fertilizer era. *International J. Agril. Sci. and Res*., **7** (3): **197-206.**

Kramer U, Talke I, Hanikenne, M (2007). Transition metal transport, FEBS Lett., **581**: 2263-2272.

Kramer U, Talke I, Hanikenne, M (2007). Transition metal transport, FEBS Lett., **581**: 2263-2272.

Martins, L.L. _and Mourato , M. P. (2006). Effect of Excess Copper on Tomato Plants: Growth Parameters, Enzyme Activities, Chlorophyll, and Mineral Content.*J.Plant Nutr.* **29:**12.

Mediouni, C. Benzarti, O, Tray, B., Ghorbel, M.H. Jemal. F. Cadmium and copper toxicity for tomato seedlings. *Agron. Sustain. Dev.*, **26**: 227–232

Meenakshi, J. V., Johnson, N. L., Manyong, V. M., Degroote, H. And Javelosa, J. (2010), How cost-effective is biofortification in combating micronutrient malnutrition*. An Ex. ante Assessment. World Dev.*, **38**: 64-75.

Mondal M. S., Yoshida, Y. and Matsui, T. (1992). Effect of chemical fertilizers on the yield attributing characters of tomato. *Trop. Sci.,* **38**(3):151-154.

Obata, 1-1., Kawamura, S., Senoo, K., and Tanaka, A. (1999).Changes in the level of protein and activity of Cu/Zn superoxide dismutase in zinc deficient rice plant, Oryza sativa L. *Soil sci .Plant Nutr.*,**45**: 891-896.

Obata, 1-1., Kawamura, S., Senoo, K., and Tanaka, A. (1999).Changes in the level of protein and activity of Cu/Zn superoxide dismutase in zinc deficient rice plant, Oryza sativa L. *Soil sci. Plant Nutr.*,**45**: 891-896.

Patnaik, M. C., G. B., Raj, and Reddy. 1. P., (2001). Response of tomato (*Solanum lycopersicumL*.) to zinc and iron. *Veg Sci.,***28** (1): 78-79.

Phytoremediation proceedings of the conference (2000) on hazardous waste research of toxic metals: Using plants to clean up the environment. John Wiley and Sons, Inc, Toronto, Canada, p. 303.

Pich, A. and Scholz, G. (1996). Translocation of copper and other micronutrients in tomato plants *(Lycopersicon esculentum* Mill.): nicotianamine-stimulated copper transport in the xylem. *J. Ex. Bot, **47** (294): 41-47.*

Pijls, L., Ashwell, M. & Lambert, J.(2009), EURRECA-A network of excellence to align European micronutrient recommendations. *Food Chem.*, **113**:748-753.

Quasem, J. M., Mazahreh, A. S. & Abu-Alruz, K.(2009), Development of vegetable based milk from decorticated sesame (Sesamum Indicum). *Am. J. Appl. Sci.,* **6**: 888-896.

Salam, M. A., Siddique, M. A., Rahim M. A., Rahman, M. A. and Goffar, M. A. 2011. Quality of tomato as influenced by boron and zinc in presence of different doses of cowdung. *Bangladesh J. Agril. Res*. **36**(1) : 151-163.

Salunkhe, D.K., Desai, B.B., and. Bhat, N.R. (1987). Vegetable and flower seed production. 1st, Edn., Agricole pub. *Acad., New Delhi, India*. P. 135.

Shams, A. S. and Nahla M. Morsy. (2014). Response of tomato plants to low plastic-zno nano-composite tunnels covering and chitosan nanoparticles foliar spraying. *J. Plant Production, Mansoura Univ.,* **5** (9): 1533-1545.

Shankar, A. H. and Prasad, A. S. (1998), Zinc and immune function: the biological basis of altered resistance to infection.*Am. J. Clin. Nutr.,* **68**: 447–463.

Singh D, Nath K, Sharma YK (2007). Response of wheat seed germination and seedling growth under copper stress. *J. Environ. Biol.,* **28**(2): 409-414.

Sommer, A. 1. And Lipman, C. B. (1926). Evidence on the indispensable nature of zinc and boron for higher green plants. *Plant Physiol.* **1**:234-249.

Stein, A. J., Meenakshi, J. V., Qaim, M., Nestel, P. & Sachdev, H. P. S.,(2008), Potential impacts of iron biofortification in India. *Soc. Sci. Med.*, **66**: 1797-1808.

Taleb, M.A. 1994. Effect of planting time, 2, 4- Dichlophenoxy acetic acid and kinetin on growth and yield of tomato. MS thesis, Dept. of Hort., BAU, Mymensingh. 124p.

Tisdale, M. K., Bufler, G., and Blemar, P. R. (1997).Interaction of nutrient management with disease control in sweet Spanish onions. In I. A. Tindall and D. Westerman (ed) Proc. Western Nutrient manage. Conf. **1** :19-126.

Ullah,R, Ayub, G. Ilyas,M. and Ahmad, G. (2015). Growth and Yield of Tomato *(Lycopersicon esculentum* L.) as Influenced by Different Levels of Zinc and Boron as Foliar Application. . *Am-Euras. J. Agric. & Environ. Sci.*, **15** (12): 2495-2498.

Vojtechova M, Leblova S (1991). Uptake of lead and cadmium by maize seedlings and the effects of heavy metals on the activity of phosphoenol pyruvate carboxilase isolated from maize. *Biol. Plant*, **33**: 386- 394.

Welch, R. M., and Graham, R. D. (2004). Breeding for micronutrients in staple food crops from a human nutrition perspective. *J Expt. Bot.*, **55**: 353-364.

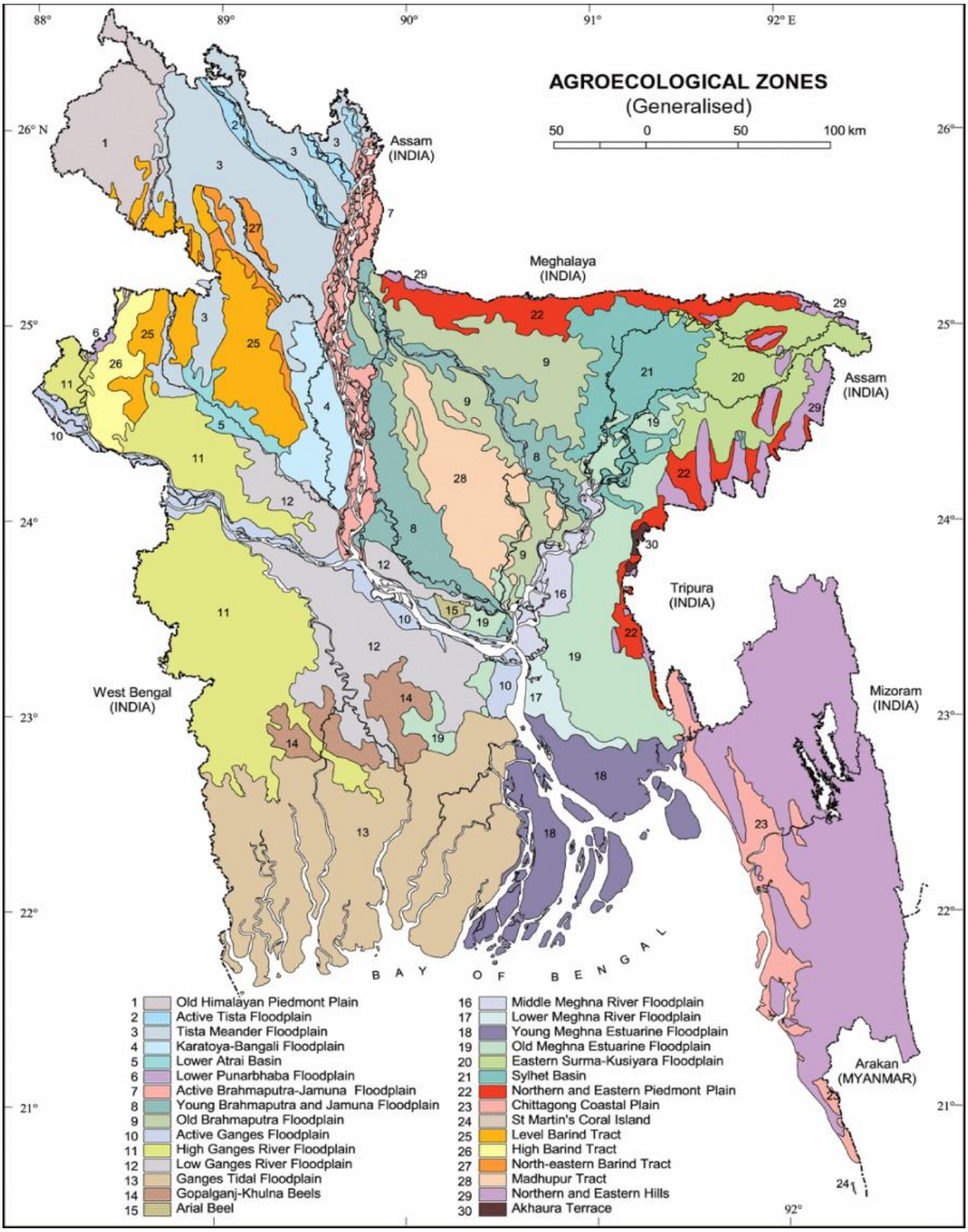
Yadav, P.V. S.,Abha-Tikkoo and Sharma, N. K.(2001a). Effect of zinc and boron application on yield, concentration and their uptake by tomato (*Solanum lycopersicum L.). Haryana J Hort Sci*., **30** (3/4): 251 -253.

Yadav, P.V.S., Abha, T., Sharma, N.K, and Tikkoo, A.(2001b).Effect of zinc and boron application on growth, flowering and fruiting of tomato (*Solanum lycopersicumL*.). *Haryana J. Hort. Sci*.**30** (1-2): 105- 107.

Zhao, F. J. & Mcgrath, S. P.(2009), Biofortification and phytoremediation. Current Opinion of Plant Biology, **12**: 373- 380.

APPENDICES

Appendix I: Experimental location on the map of agro-ecological zones of Bangladesh



Appendix II: **Soil characteristics of experimental farm of Sher-e-Bangla Agricultural University are analyzed by soil Resources Development Institute (SRDI), Farmgate, Dhaka.**

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Farm, SAU, Dhaka
AEZ	Modhupur tract (28)
General soil type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	**N/A**

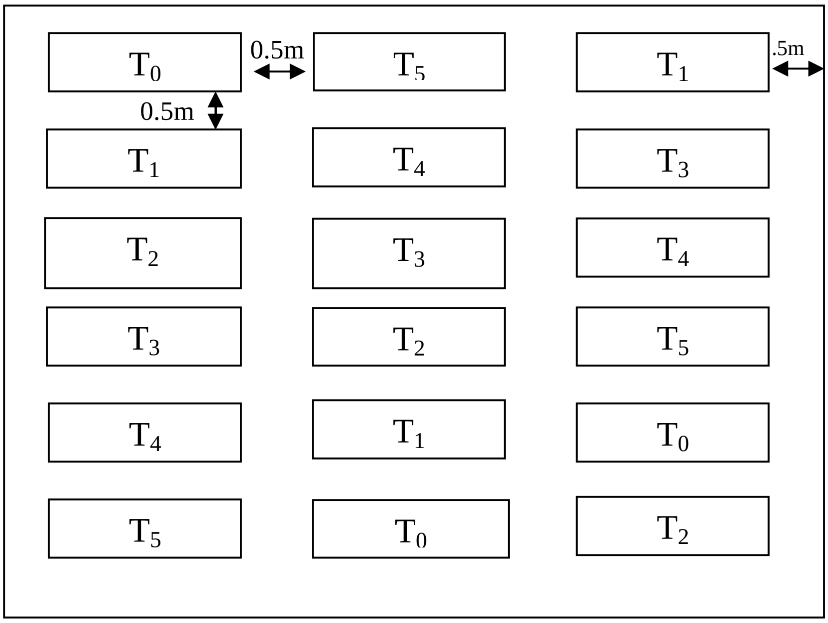
Source: SRDI

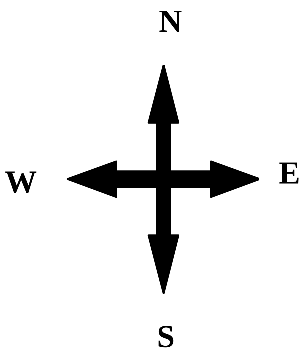
B. Physical and chemical properties of the initial soil

Characteristics	Value
Practical size analysis	
Sand (%)	16
Silt (%)	56
Clay (%)	28
Silt + Clay (%)	84
Textural class	Silty clay loam
pH	5.56
Organic matter (%)	0.25
Total N (%)	0.02
Available P (µgm/gm soil)	53.64
Available K (me/100g soil)	0.13
Available S (µgm/gm soil)	9.40
Available Zn (µgm/gm soil)	0.94
Available Cu (µgm/gm soil)	1.93

Source: SRDI

Appendix III. Layout and design of the experimental plot





a) **Treatment**

T_0= Control
T_1= Recommended dose of $(N_{160}P_{50}K_{100}S_{20}$)kg/ha fertilizers.
T_2=75% NPKS from inorganic fertilizer and 25% NPKS from cowdung.
T_3= Recommended dose of $(N_{160}P_{50}K_{100}S_{20}+Zn_4+Cu_4)$kg /ha
T_4= Recommended dose of $(N_{160}P_{50}K_{100}S_{20}+Cu_4)$kg/ha
T_5= Recommended dose of $N_{160}P_{50}K_{100}S_{20}+Zn_4$

Appendix IV: Analysis of variance of the data on Plant height, Number of leaf per plantand Number of branch per plant of tomato as influenced by different Zn and Cu

Sources of Variation	Degrees of freedom	Mean Square		
		Plant height (cm)	Number of leaf per plant	Number of branch per plant
Replication	2	12.06	0.222	3.56
Factor A	5	33.82*	168.36*	0.989[NS]
Error	10	2.52	7.62	0.76

*significant at 5% level of probability
NS- Non significant

Appendix V: Analysis of variance of the data on Number of flower Cluster per plant, Number of flower per plant and Number of fruit per plant of tomato as influenced by Zn and Cu

Sources of Variation	Degrees of freedom	Mean Square		
		Number of flower Cluster per plant	Number of flower per plant	Number of fruit per plant
Replication	2	1.56	26.06	0.722
Factor A	5	4.49*	52.89*	69.69*
Error	10	1.76	3.39	3.86

*significant at 5% level of probability

Appendix VI: Analysis of variance of the data on Yield of fruits (g) per plant and Dry weight of fruit of tomato as influenced by Zn and Cu

Sources of Variation	Degrees of freedom	Mean Square	
		Yield of fruits (g) per plant	Dry weight of fruit
Replication	2	424.85	00.0001
Factor A	5	10430.73*	0.001*
Error	10	213.35	0.0001

*significant at 5% level of probability

Appendix Fig 1: Tomato experiment in the net-house

Appendix Fig 2: Flowering of tomato Plant

Appendix Fig 3 : Fruiting of tomato plant