EFFECT OF ZINC AND MOLYBDENUM ON THE YIELD AND QUALITY OF BARI TOMATO-9 (LALIMA) (*Lycopersicon esculentum* Mill.) AND THE POST HARVEST SOIL

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A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE
IN
SOIL SCIENCE

SEMESTER: JULY-DECEMBER, 2009

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CERTIFICATE

*This is to certify that the thesis entitled "Effect Of Zinc and Molybdenum on the Yield and Quality Of BARI Tomato-9 (Lalima) and the Post Harvest Soil" submitted to the Department 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, embodies the result of a piece of bona fide research work carried out by **Alamgir Kabir**, Registration No. **08-03177** 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.

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DEDICATED TO MY

Beloved Parents

ACKNOWLEDGEMENTS

At every moment the author would like to express his profound gratefulness to the Almightily Allah, the merciful and the beneficent to all creations for blessing to present this thesis.

The author wishes to express his sincere gratitude and indebtedness to his honorable teacher and research Supervisor Associate Professor A.T.M. Shamsuddhoha, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance, outstanding assistance, valuable advice and suggestions for the successful completion of the research work and preparation of this manuscript.

The author sincerely expresses his heartfelt gratitude and deepest sense to his Co-supervisor Professor Dr.Md. Nurul Islam, Department of Soil Science, Sher-E-Bangla Agricultural University, for his kind co-operation and constructive suggestions in all phases of the research work.

The author whishes to pay his gratefulness to all the honorable teachers of the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for their kind illuminating suggestions during the research work period. The author is proud to express his heartiest gratitude to his parents and elder brother for their sacrifice and rendered inspiration for his higher study.

The author thanks to Assistant professors Md. Mosharraf Hossain and Jharna Rani Sarker for their cordial co-operation and inspiration during the research work. The author extends his cordial thanks to his all friends especially Kader, Bulbul, Zahangir, Rumi, Gobindo, Biplob Senior brother Rafique, Sajib Junior brother Jabbar,Jewel,Dalina and well-wishers for their co-operation and sacrifice during the experiment period and preparing this manuscript.

Last, but not least, the heartfelt gratitude and indebtedness is expressed to the authors beloved Father-Mozibar Rahaman, Mother-Tajkara Begum, Brothers-Md. Zanghir Alam, Kajol, Mustaqim, Masud, Sujon, Rony, Sabbir, Samir, Sister- Liza, Niece- Mariam, Sumaiya, and all relatives for their affectionate feelings, helpful suggestions and encouragement during the study that enabled the author to reach up this higher level of education and proper completion of the research work.

Dated

Place: SAU Dhaka ***The Author***

ABSTRACT

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University farm, during the period from December 2008 to March 2009 to find out the effect of zinc and molybdenum on the yield and quality of tomato. The experiment consisted of two factors as A (Four levels of zinc): Zn_0: 0 kg Zn/ha, Zn_3: 3 kg Zn/ha, Zn_6: 6 kg Zn/ha, Zn_9: 9 kg Zn/ha, and B (Four levels of Molybdenum): M_0: 0 kg Mo/ha, $Mo_{0.5}$: 0.5 kg Mo/ha, $Mo_{1.0}$: 1.0 kg Mo/ha, $Mo_{1.5}$: 1.5 kg Mo/ha. In case of zinc treatment, plant height, number of leaf, number of flower cluster, number of flower, number of fruit, single fruit weight, vitamin-C content and yield increased significantly with increasing Zn level up to 6 kg Zn/ha (Zn_6) whereas vitamin-A content increased significantly up to 9 kg Zn/ha (Zn_9). The maximum plant height (63.63), fruit number (44.17), vitamin-C content (17.52 mg/100g) and yield (44.26 t/ha) were recorded from Zn_6 treatment. The maximum vitamin-A content with Zn_9 was (6444.0 μg/100g). The maximum zinc (361.50 ppm) uptake was recorded from Zn_9 treatment and the minimum zinc (190.3 ppm) uptake was recorded from Zn_0 treatment. In case of molybdenum treatment, plant height, number of leaf, number of flower cluster, number of flower, number of fruit, single fruit weight, vitamin content and yield increased significantly with increasing Mo level upto 1.0 kg Mo/ha ($Mo_{1.0}$) where as vitamin-A content increased significantly up to 1.5 kg Mo/ha ($Mo_{1.5}$). The maximum plant height (62.70 cm), fruit number (42.49), vitamin-C content (16.24 mg/100g) and yield (41.46 t/ha) were recorded from $Mo_{1.0}$ treatment. The maximum vitamin-A content with $M_{1.5}$ was (6047.0 μg/100g). The combined effect of Zn and Mo showed that the combination of $Zn_6M_{1.0}$ as 6 kg Zn/ha+1.0 kg Mo/ha gave the highest yield (4706 t/ha) and vitamin-C content (18.60 mg/100g) while the highest vitamin-A content was obtained from the combination $Zn_6Mo_{1.5}$.

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Chapter I
Introduction

INTRODUCTION

Tomato *(Lycopersicon esculentum Mill.)*, belonging to the family Solanaccae, is one of the most popular and quality vegetables grown in Bangladesh. In Bangladesh, tomato has great demand throughout the year. Its production is mainly concentrated during the winter season. Recent statistics showed that tomato was grown in 50470 acre of land and the total production was approximately 150720 metric tons in 2008-2009 (BBS. 2009). Thus the average yield of tomato was 7.38 t ha^{-1} (BBS, 2009), while it was 69.41 t ha^{-1} in USA, 14.27 t ha^{-1} in India, 26.13 t ha^{-1} in China, 13.25 t ha^{-1} in Indonesia and 9.26 t ha^{-1} in Japan (FAO, 2002). Food value of tomato is very rich because of its higher contents of Vitamins A, B, and C including calcium and carotene (Bose and Som, 1990).The low yield of tomato in Bangladesh, however, is not an indication of low yield 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, improper management of fertilizers, irrigation, disease control etc.

Micronutrients play an important role in tomato production. It is well known that micronutrient deficiencies are one of the major limiting factors for crops production in most tropical woody deep peat soils (Tadano, 1985). Among the micro elements, boron and zinc play an important role directly and indirectly in improving the yield and quality of tomato in addition to checking various diseases and physiological disorders (Magalhaes *et al.*, 1980). Zinc mainly function as the metal component of a series of enzymes. The most important enzymes activate by this element are carbonic anhydrase and a number of dehydrogenases. Zinc deficiency is thought to restrict RNA synthesis, which in turn inhibits protein synthesis (Katyal and Randhawa, 1983). Zinc is also involved in auxin production. Shoots and buds of zinc deficient plants contain very low auxin, which causes dwarfism and growth reduction. The net results are stunted plants and prolonged duration of growth. Like boron, Zinc deficiency is found to occur in high pH soils (Keren and Albright 1985). It also plays an important role in chlorophyll formation, cell division, meristematic activity of tissue expansion of cell and formation of cell wall. Zinc application also helps in increasing the uptake of nitrogen and potassium. Application of zinc sulphate, copper sulphate and ammonium molybdate estimated chlorophyll synthesis and fruit quality of tomato (Kalloo, 1985). Zinc provides a protective mechanism against the excessive uptake of boron. Zinc is necessary for root cell membrane integrity and in this function it prevents excessive phosphorus uptake by roots and the transport of phosphorus from roots to leaves (Noion *et al.* 1982).

Molybdenum occurs in the soil solution as MoO_4^{2-} (molybdate) ion. It exists in very low amount in soil and needed by plants in very small quantities. The total Mo content of most agricultural soils lies between 0.2 to 5 $\mu g\ g^{-1}$ with an average content of 2 $\mu g\ g^{-1}$ (Tisdale *et al.* 1997). Most plant molybdate exists as part of the enzyme nitrate reductase. Mo is also needed in the N fixation enzyme nitrogenase. Mo deficiency is usually common in acid soils, where leaching losses, strong molybdate adsorption and few Mo minerals occur. Soils high in metal oxides (sesquioxides) have low Mo availabilities (Miller & Donhue, 1997).

Only three primary plant nutrients viz. nitrogen, phosphorus and potassium along with one secondary nutrient are used by the farmers of Bangladesh for the cultivation of tomato. The importance of the use of micro nutrient is mostly ignored although they can be a chief limiting factor for crop production. Presently there has been great increase fertilizer use, yet the proportion of different nutrients used in the country is not at all balanced. N alone constitutes about 78% of the total nutrients used in the country which may not help improve crop productivity unless other limiting nutrients are supplemented along with nitrogen.

In order to improve crop productivity, the limiting micro nutrient (s) must be identified and the soils should be enriched with addition of these nutrients in properly balanced fertilizer programmed.

In Bangladesh, there is a great possibility of increasing the yield of tomato in per unit area with the judicious use of fertilizers. Until 1950, farmers need not to use any chemical fertilizers to grow crops. Because they had available land, lots of cow dung and crop residues to apply into the soil. Production is not enough for providing food for population of that time. Now, high yielding varieties (HYV) are being used to get higher yield for over increasing population. Intensive cropping with HYV is mining large amount of nutrients from the soil without replenishing. So, by depleting soil fertility, soils have been becoming barren day by day and deficiency of different nutrients has been developing one by one. Until 1990, farmers used only NPK fertilizers but now they are applying sulphur and zinc along with NPK. Following Zn and S, addition of Zinc, boron, manganese, copper or calcium is needed in some soils (Islam 1992). Again, deficiencies of Zinc and molybdenum are also reported on some soils and crops. (Islam *et al.*,1997).

In order to increase the yield, quality and shelf life of tomato, there should have the technologies which will eventually fulfill the growers as well as consumers need. Studies on management practices, particularly on the management of zinc and molybdenum would help increasing yield, quality and shelf life of tomato. Available information on the state subject under Bangladesh conditions is inadequate. The present investigation was therefore, carried out with a view to achieving the following objectives:

- To study the effect of zinc and molybdenum on yield and yield attributes of tomato;
- To find out the effect of zinc and molybdenum on some growth characteristics of tomato; and
- To observe the influence of zinc and molybdenum on the quality of tomato.

Chapter II
Review of Literature

REVIEW OF LITERATURE

Tomato is one of the most popular and widely grown vegetable of the world. It is a rich source of minerals and vitamins. Market price is dictated by the quality of a commodity and demand-supply. So, it is essential to know the physico-chemical properties, which determine the quality of fruits. The quality of tomato fruit is largely dependent on the macro and micro nutrient application. Available literature and finding on tomato, which are related to the present study has been cited in the following sections.

2.1 Effect of Zinc on yield and yield attributes

Mondal *et al.* (1992) reported that application of Ca, Mg, Mo and Zn increased the plant height, number of fruit branches and fruits per plant. The yield and size distribution of tomato were also improved due to the application of Ca, Mg, Mo and Zn.

Yadav *et al.* (2001) conducted a field experiment at Hisar, Haryana, India in 1990 and 1991 to study the effect of zinc (0, 5, 10, 15, and 20 kg zinc 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 treatments significantly increased tomato yield. The maximum yield was obtained with 15 kg $ZnSO_4$< sub>4</ sub>/ha and 2 kg B/ha. The highest concentration and uptake of zinc and boron were recorded for 20 kg $ZnSO_4$< sub>4</ sub> and 4 kg boron/ha, respectively.

The effects 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 were studied in a pot experiment by Dube *et al.* (2003). The 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. Zn at 10 mg/kg tended to have an adverse effect on fruit quality. The contents of P, Fe, Mn and Cu generally decreased with the increase in Zn concentration. The Zn content of leaves was highest at the highest rate of Zn.

Dube *et al.* (2003) conducted a field experiment during 1995-98 in Bijnor, Uttar Pradesh, India, to determine the effect of zinc fertilizer (application rates and methods) on the growth and yield of tomato (cv. Pant T-3)-okra (cv. Parbhani Kranti)vegetable pea (cv. Pant Uphar) cropping sequence. The treatments comprised: basal application of 10, 20, 30 and 40 kg zinc sulphate/ha; foliar spray of 2.5 and 5.0 kg zinc sulphate/ha, once at 25 days after transplanting (DAT)/days after sowing (DAS) and twice at 25 and 40 DAT/DAS; and basal application of 2.5 and 5.0 kg zinc sulphate/ha followed by one foliar spray of zinc sulphate at 25 DAS/DAT. The basal application of 40 kg zinc sulphate/ha gave the highest plant height, fruit weight and yield in tomato (69.3 cm, 210.3 g and 215.7 q/ha, respectively), okra (69.5 cm, 21.3 g and 54.5 q/ha, respectively) and pea (48.7 cm, 22.3 g and 46.2 q/ha, respectively).

Yadav *et al.* (2001) 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.

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 12.5 and 25 kg $ZnSO_4$/ha, soil application of 12.5 kg $ZnSO_4$/ha + foliar spray of 0.2% $ZnSO_4$ (thrice at weekly interval), soil application of 12.5 kg $ZnSO_4$/ha + 0.5% $FeSO_4$ spray (thrice at weekly interval), and soil application of 12.5 kg $ZnSO_4$/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 39.88 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 $ZnSO_4$ soil application along with 0.2% $ZnSO_4$ and 0.5% $FeSO_4$ sprays.

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 rsulted in marked increases 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 P and Fe concentrations.

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 43.4%, compared with the untreated control.

Each nutrient has a positive impact on vegetative growth as well as on yield and yield attributes of tomato. Rahman *et al.* (1996) obtained the highest yield (45 t/ha) of tomato with 200 kg N, 100 kg P_2O_5, 150 kg K_2O, 20 kg Zn and 5 t cowdung/ha.

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.*, 2001). Application of soil test based NPK combined with Boraz (10 kg/ha), Zinc sulphate (50 kg/ha) ad composed coirpith (5 t/ha) was reported to give the highest fruit yield of tomato.

Sommer and Lipman (1926) were the first to prove the essentiality of Zn as a nutritent requirement for higher plants. Plants absorb zinc in the form of Zn^{2+}. The functional role of Zn includes auxins metabolism, nitrogen metabolism, inflence on the activities of enzymes (e.g. dehydrogenase and carbonic anhydrase, proteinases and peptidases), cytochrome C synthesis, stabilization of ribosomal fractions and protection of cells against oxidative stress (Tisdale *et al.* 1997; Obata *et al.*, 1999). The normal concentration on Zn in dry matter of plant ranges from 25 to 150 $\mu g\ g^{-1}$. Deficiencies are usually associated with leaf concentration of less than 20 $\mu g\ g^{-1}$ and toxicity may arise when the Zn level in leaf exceeds 400 $\mu g\ g^{-1}$.

Zinc concentration is higher in legume crops than in cereals, Its concentrations were found to be on an average 18, 30, 39 and 55 $\mu g\ g^{-1}$ in grain of corn, rice, dry bean 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).

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 biofortility major staple crops with Zn, Fe, and vitamin A (Welch and Graham, 2004). Biofortification 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 al.,* 2001). Plants emerged from seed with low concentrations of Zn could be highly sensitive to biotic and abiotic stresses (Obata *et al.,* 1999). Zinc enriched seeds can perform better with respect to seed germination, seedling health growth and finally yield advantage (Cakmak *et al.*, 1996).

Yilmarz *et al.* (1997) stated that higher amounts of Zn in the grain, beyond levels required for optimum crop yield would be required to address Zn malnutrition in people and one important strategy to increase micronutrient concentration in grain could be fertilization of plants via soils and foliar application. There is an opportunity i.e. an alternative way to develop new plant genotypes with high genetic capacity for enhanced root uptake, shoot translocation and seed loading of micronutrients (Cakmak *et al.*,2004). Increasing micronutrient concentrations in edible parts of plants through biofortification is a sustainable approach with low cost, high efficacy and large coverage, especially to the poor population (Graham *et al.,* 2001).

Hossain el *al.* (2008) conducted experiments over 3 years to find out an optimum rate of Zn 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^{-1} for maize (cv. Pacific 984, Thai hybrid) and at 0, 1 and 2 kg ha^{-1} for rice (cv. BRRI dhan-33), with no Zn application for mungbean (cv. BARI mung-5). Effect of Zn was evaluated in terms of yield and mineral nutrients 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^{-1} for the first year and 2-0-2 kg ha^{-1} for subsequent years particularly when mungbean residue was removed, and such rates of mungbean residue incorporation being 4-0-1 and 2-0-1 kg ha^{-1}, respectively. For all crops, the Zn and N concentrations of grain were significantly increased with Zn application.

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

2.2 Effect of molybdenum on yield and yield attributes

Freeh (1989) reported that the importance of molybdenum for plant growth is disproportionate with respect to the absolute amounts required by most plants. Apart from Cu, Mo is the least abundant essential micronutrient found in most plant tissues and is often set as the base from which all other nutrients are compared and measured. Molybdenum is utilized by selected enzymes to carry out redox reactions. Enzymes that require molybdenum for activity included nitrate reductase, xatlthinc dehydrogenase, aldehyde oxiciase and sulfite oxidase.

Frazeria *et al.* (1981) stated that molybdenum has been found to have a role in the biology of all classes of organisms. It was found in two groups of enzymes: the nitrogenases and the molybdopterins.

Jain (1973) reported that the yield of tomato *(Lycopersicon esculention* Mill.*)* was increased significantly by Mo application.

Mudholkar and Ahlawat (1979) shoewed that application of phosphorus and molybdenum enhanced plant productivityand the grain yield significantly. Nitrogen application failed to affect the yield component and yield of chickpea.

Das and Patro (1985) carried out an experiment on tomato cv. Marglobe at Bhubaneswar, India, during 1979-80. Seedlings (33 days old) were planted in plots treated with 30 kg N 50 kg P_2O_5 and 50 kg K_2O ha^{-1}. Micronutrients 0.075% Mo (as ammonium molybdate), 0.10% Zn (as zinc sulphate), 0.25% B (as boric acid), 0.04% Cu (as copper sulphate), alone or in combination and/or 2% urea, were applied as foliar sprays. Effects on the growth yield; disease (bacterial wilt, viruses) incidence and fruit quality are tabulated. The best plant growth and highest yield (298 q ha^{-1}) and yield attributes were obtained with urea followed by Mo or B.

Bennet (1989) reported that tomato plants of the cultivar flora Dade required supplementary fertilization with low Mo requirements.

Shanna and Chahal (1983) carried out a field experiment in Ludhiana, India and observed that soil treatment with 10 to 15 µg/*g* Mo increased the shoot length and dry weight of tomato plants.

Naphade and Wankhade (1987) observed that growth and growth attribute of tomato was increased significantly with 50 kg S and 1.5 kg Mo ha^{-1}.

Ahmed (1988) observed that Mo application increased seed yield of green gram (*Vigna radiata*) by 28% and dry matter yield by 34%. All the trace element treatments increased yield compared with the control.

Bertic *et al.* (1991) reported that application of Mo (1.5 kg ha^{-1}) increased average yield of tomato significantly.

Sarkar and Banik (1991) noted that Mo could not bring substantial improvement in yield attributes and yield of tomato. Through application of N and P improved plant productivity and enhanced the yield, fruit weight, number of flowers of tomato plant significantly.

Solaiman *et al.* (1991) carried out an experiment with two varieties of lentil. Utfala and Mymensingh local and reported that 1.5 kg Mo ha^{-1} when applied with

Rhizohiitm inoculants was found stimulating in respect of nodulation and dry matter production of the crop.

Singh *et al.* (1992) noted that application of Mn and Mo either singly or in combination with *Rhizohium* culture significantly increased the grain yield of cow pea. Protein content of grain and available nitrogen in soil also increased with increasing dose of Mn and Mo with *Rhizobium* inoculants.

2.3 Changes in chemical characteristics of fruits

2.3.1 Ascorbic acid and carotinoids content in tomato

Tomatoes are rich source of ascorbic acid which varied from 15 to 65 mg per 100 g juice of fruits of different varieties and approximately 11.2 to 21.6 mg 100 g^{-1} of fruit weight.

The contents of vitamin-C, carotene and lycopene were determined for different *tomato* varieties by Navez *et al.* (2004) and found that variety was a determining factor for chemical composition. Maintaining overall quality, Mg, Zn and Mo had a positive effect on vitamin C content. The contents of lycopene and carotene were influenced by growing conditions, which reduced the risk of human diseases such as prostate cancer.

Davis and Hobson (1981) found the following composition in ripe tomato (% drymatter basis) sugars 48%, protein 8%, peptic substances 7% hemiceliuloses 4%, cellulose 6%, organic acids 13%, minerals (mainly K^+, Ca, Mg, P) 8%, lipids 2%, dicarboxylic amino acids 2%, ascorbic acid 0.5% pigments 0.4%, volatiles 0.1% and other amino acids, vitamins and polyphenols 1% (100%). They also stated that, tomato is very important source of vitamin A and C. About 100 g tomato could supply 20% and 40% of the US recommended daily allowances of vitamins A and C, respectively for adults.

Dobromilska *et al.* (2004) conducted an experiment at the Horticultural Experimental Station of the Agricultural University in Szczecin and proved that some less popular vegetables; cherry tomato, broccoli and fennel possessed high nutritional value. The contents of dry matter, beta-carotene, sugars, vitamin C and N, P, K, Ca and Mg were determined in edible parts of vegetables. Agro-technical factors (bunch cutting, plant covering) and cultivars modified the nutritional value and mineral composition of the vegetables species tested.

El-Gharably *et al.* (2004) studied the stability of vitamin-C in storage and found that vitamin-C contents decreased with increasing storage period. However, control drinks had the highest less rates of vitamin C being 77, 100, 81, 100 and 89% for strawberry, apple, mango, apricot and tomato drinks after 6 months of storage; respectively. On the other hand, data showed that enriched tomato drinks had the best highest sensory evaluation scores followed by strawberry, apricot, apple and mango drinks, respectively either for fresh prepared or 6 months of stored drinks.

Hanson *et al.* (2004) stated that tomato among the most widely consumed worldwide vegetable is an important source of certain antioxidants (AO) including lycopene, beta-carotene and vitamin-C. Improvement of tomato for content of AO and overall antioxidant activity (AOA) could be potential by benefit human health in many countries. Lycopene, beta-carotene, ascorbic acid. Soluble solids and total phenolics were positively correlated with ARP (anti-radical power). Among AO, total phenolics content was most closely associated with ARP and ILP (inhibition of lipid peroxidation). This suggests that phenolic make a major contribution of AOA in tomato fruit. Fruit size was negatively correlated with ARP and ILP indicating that combining large fruit size and high AOA will be challenging.

Singh *and Sharma.* (1993) showed that vitamin-C content of tomato decreased as the CO_2 concentration in the storage atmosphere increased. Vitamin-C contents increased with the stored period.

Dutta *et al.* (1995) studied wit six tomato varieties including two advanced lines and observed that the advanced line, contained higher ascorbic acid than the other varieties. A wide range of variation in the acid content of different cultivars was also reported by Saimbhi *et al.* (1987) and Bajaj *et al.* (1990).

Dod and Kale *(1997)* studied the performance and quality characters of 12 tomato varieties and observed a wide range of variation in ascorbic acid content. Chameli had less ascorbic acid content *(14.20%)*, whereas the HIS 101 had the highest ascorbic acid content (25.0%).

Sidhu and Singh (1989) studied 11 tomato varieties and observed that the genotypic co-efficient was highest for ascorbic acid content (21.44%) among the fruits.

Awasthi et al. (1992) did not find any significant difference in ascorbic acid content among four Indian varieties of tomato. The highest ascorbic acid content was found in Pusa-Ruby (41.1%) and lowest in H.S.101.

Chapter III
Materials and Methods

MATERIALS AND METHODS

This chapter presents a detailed description about the work which is related to the experiment. It represents a brief description about the experimental site, soil, climate, crops, treatments, experimental design followed, land preparation, seedling transplanting, intercultural operations, harvesting, data recording, collection and preparation of soil and plant samples and the methods for the chemical and statistical analysis.

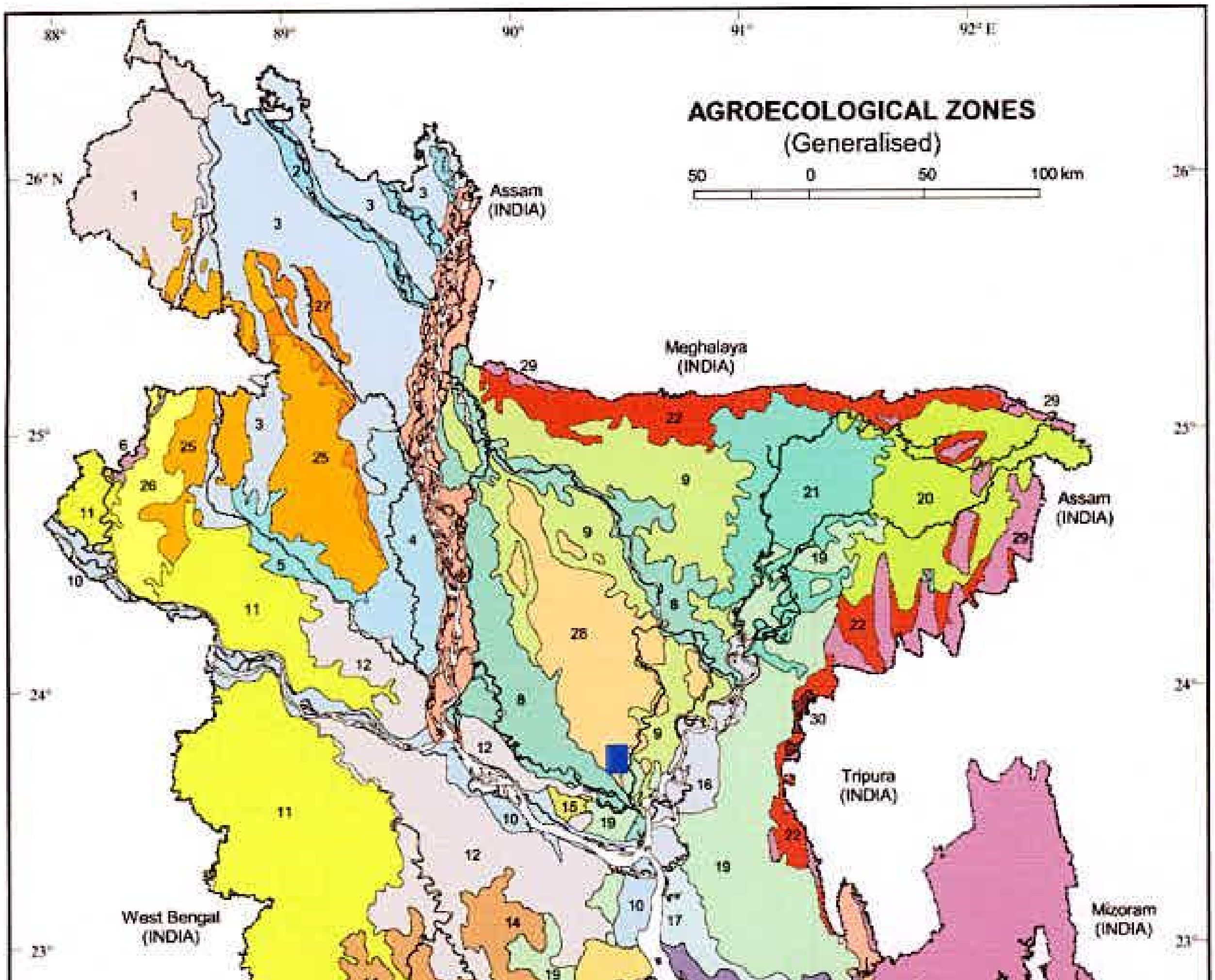
3.1 Description of the experimental site

3.1.1 Location

The research work was conducted in *rabi* season at Sher-e-Bangla Agricultural university Farm, Sher-e-Bangla Nagar, Dhaka-1207 during the *rabi* season of December, 2008. It is located at 90.335^{0}E longitude and 23.774^{0} latitude.The specific location of experimental site is presented in Figure 1.

3.1.2 Soil

The soil of the experimental field belongs to the Tejgaon series of AEZ No. 28, Madhupur Tract and has been classified as Shallow Red Brown Terrace Soils in Bangladesh soil classification system. A composite soil sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The collected soil was air-dried, ground and passed through 2 mm sieve and analyzed for some important physical and chemical parameters. Some initial morphological, physical and chemical characteristics of the soil are presented in Table 1and 2.



■Location of the experimental site

Figure 1: Map showing the experimental site under study

Table 1. Physical and chemical properties of the initial soil

Soil properties	Value
A. Physical properties	
1. Particle size analysis of soil.	
% Sand	28.2
% Silt	41.20
% Clay	30.6
2. Soil texture	Silty Clay
B. Chemical properties	
1. Soil pH	5.6
2. Organic carbon (%)	0.68
3. Organic matter (%)	1.17
4. Total N (%)	0.08
5. C : N ratio	9.75 : 1
6. Available P (ppm)	12.82
7. Available K (ppm)	0.10
8. Available S (meq/100g soil)	22.94
9. Available Zn (ppm)	3.10

Table 2. Morphological characteristics of experimental field

Morphological features	**characteristics**
location	Sher-e-Bangla Agricultural University
AEZ no. and name	AEZ-28, Madhupur tract
General soil type	Deep Bed Brown Terrace Soil
Soil series	Tejgaon
Topography	Fairly leveled
Depth of inundation	Above flood level
Drainage condition	Well drained
Land type	High land

3.1.3 Climate

The experimental area has sub tropical climate characterized by heavy rainfall during May to September and scanty rainfall during rest of the year. The annual precipitation of the site is 2152 mm and potential evapotranspiration is 1297 mm. The experiment was carried out during *rabi* season of 2008-09. Air temperature during the cropping period ranged from 13.32^{0}C to 29.52^{0}C. The relative humidity varied from 45.79% to 56.20% and monthly rainfall varied from 2.3 mm to 4.01mm from the beginning of the experiment to harvest. The monthly maximum and minimum temperature, humidity and rainfall of the site during the experimental period are given in appendix Table 1.

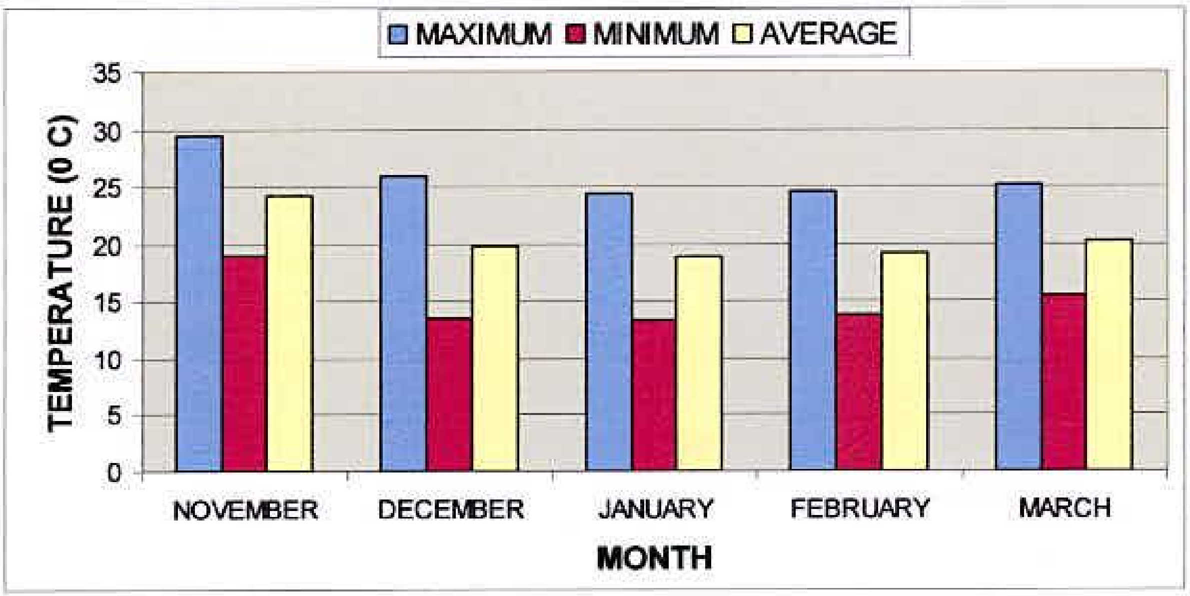


Figure 2: Monthly average, maximum and minimum air temperature (^{o}C) of the experimental site, Dhaka during the growing time (November, 2008 to March 2009)

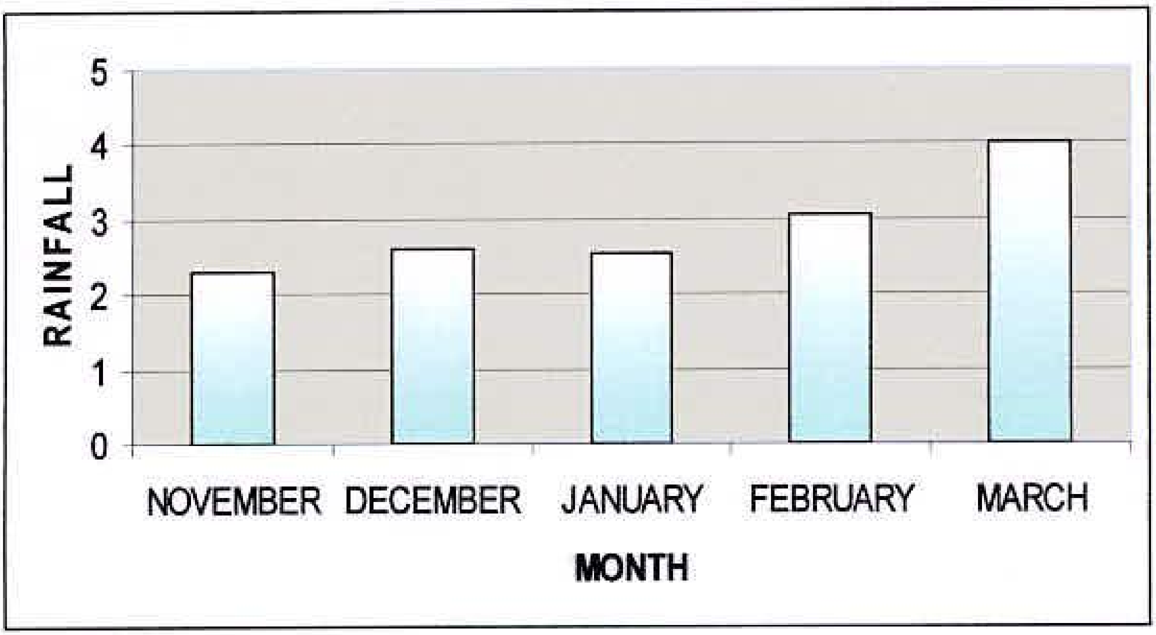


Figure 3: Monthly total rainfall (mm) of the experimental site, Dhaka during the growing period (November, 2008 to March 2009)

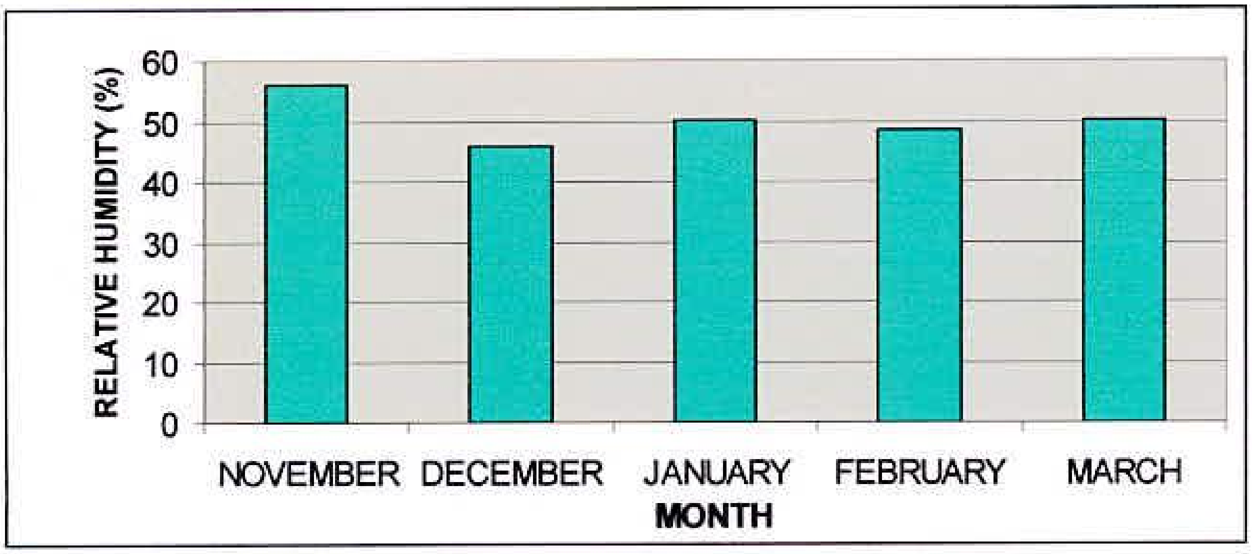


Figure 4: Monthly average relative humidity (%) of the experimental site, Dhaka during the growing period (November, 2008 to March 2009)

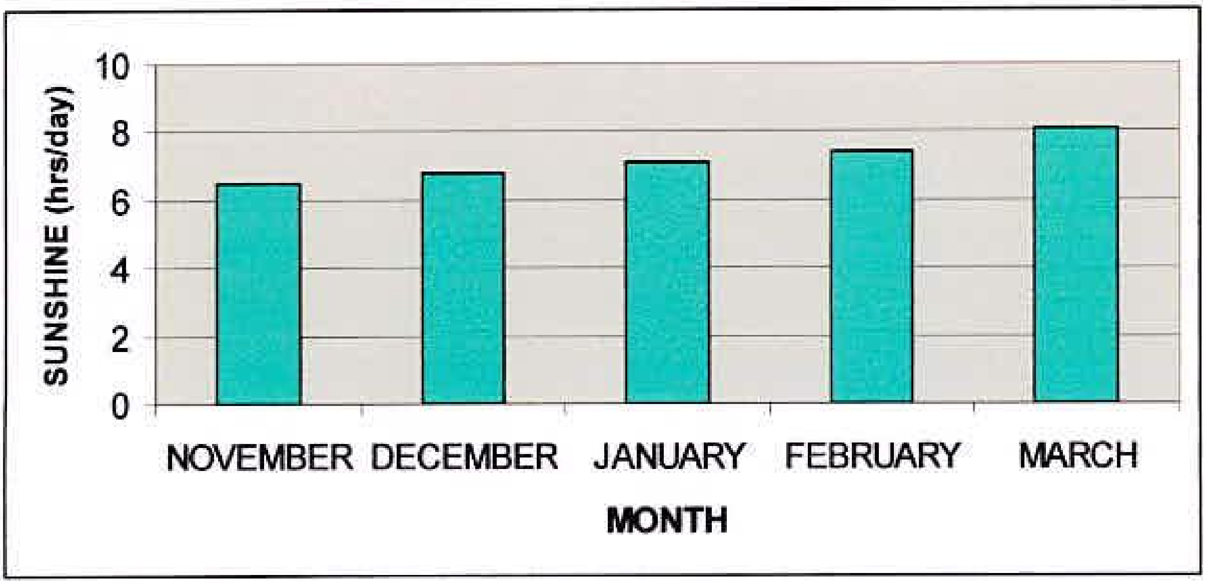


Figure 5: Monthly average sunshine (hrs/day) of the experimental site, Dhaka during the growing period (November, 2008 to March 2009)

3.2 Plant materials used

The tomato variety used in the experiment with BARI Tomato-9 (Lalima). This is a high yielding type of variety. The seed were collected from the BARI, Gazipur, Dhaka.

3.3 Raising of seedlings

The land selected for raising seedlings was light in texture and well drained. The land was ploughed well and left for drying for 10 days. Bigger clods were broken into pieces and finally the soil was made loose and friable. All weeds and stubbles were removed and then the soil of seedbeds were mixed with well-decomposed cow dung @ 12 t ha^{-1}; applying Furadan 3G @ 20 kg ha^{-1} were covered by polythene for two days. The seedbeds were 3 m × 1 m in size with height of about 20 cm. Tomato seeds were soaked overnight (12 hours) in water and allowed to burgeon in a piece of moist cloth keeping in the sunshade for one day. Then seeds were sown directly in the raised seedbed on 17th November' 2008 for raising seedlings. Irrigation was provided regularly and seedbeds were always kept free from weeds. The young seedlings were exposed to dew by night and mild sunshine in the morning and evening. To retain the soil moisture and to save the seedlings from direct sunlight and rain, shades were given over the seedbeds. Seedlings were not attacked by any kinds of insects and diseases.

3.4 Treatments of the experiment

There were 16 treatments combinations consisting of four doses of both zinc (0, 3, 6 and 9 kg ha^{-1}) and molybdenum (0, 0.5, 1.0 and 1.5 kg ha^{-1}). The treatments are as follows:

Zn_0 : Control
Zn_3 : 3 Kg Zn ha^{-1}
Zn_6 : 6 Kg Zn ha^{-1}
Zn_9 : 9 Kg Zn ha^{-1}

Mo_o : Control
$Mo_{0.5}$: 0.5 kg Mo ha^{-1}
$Mo_{1.0}$: 1.0 Kg Mo ha^{-1}
$M0_{1.5}$: 1.5 Kg Mo ha^{-1}

The 16 treatment combinations of zinc and molybdenum used in the experiment were as follow:

1. $Zn_0 Mo_0$	5. $Zn_3 Mo_0$	9. $Zn_6 Mo_0$	13. $Zn_9 Mo_0$
2. $Zn_0 Mo_{0.5}$	6. $Zn_3 Mo_{0.5}$	10. $Zn_6 Mo_{0.5}$	14. $Zn_9 Mo_{0.5}$
3. $Zn_0 Mo_{1.0}$	7. $Zn_3 Mo_{1.0}$	11. $Zn_6 Mo_{1.0}$	15. $Zn_9 Mo_{1.0}$
4. $Zn_0 Mo_{1.5}$	8. $Zn_3 Mo_{1.5}$	12. $Zn_6 Mo_{1.5}$	16. $Zn_9 Mo_{1.5}$

Every treatment received nitrogen, phosphorus, potassium, boron and sulphur as basal doses. The doses and sources of different nutrients used in the experiment are given in the following table.

Table 3. Dose and source of fertilizer in experiment field

Nutrient element	Source	Rate ha^{-1}
Nitrogen	**Urea**	**500 kg/ha**
Phosphorus	TSP	120 kg/ha
Potassium	MP	100 kg/ha
Sulphur	Gypsum	50 kg/ha
Boron	Borax	2 kg/ ha
Cowdung	SAU Farm	12t/ha

3.5 Design and layout of the experiment

The experiment consisted of 16 treatment combinations and was laid out in Randomized Complete Block Design (RCBD) with 3 replications. An area of 390 m^2 was divided into three equal blocks, representing the replications, each containing 16 plots. Thus, the total numbers of unit plots were 48, each measuring 3m×1.5m (4.5m^2). The treatment combinations of the experiment were assigned at random into 16 plots of each at 3 replications. The space between two plots was 50 cm and between blocks was 100 cm. The layout of the experiment is presented in Figure 6.

3.6 Preparation of plot

The plot selected for the experiment was opened by a tractor on the 17th December' 2008, afterwards the land was ploughed and cross-ploughed several times with the help of a power tiller followed by laddering to obtain a good tilth. Weeds and stubbles were removed, and the large clods were broken into smaller pieces to obtain a desirable tilth of friable soil for transplanting of seedlings. Finally, the land was leveled and the experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in the following section (6). Irrigation and drainage channels were prepared around the plots.

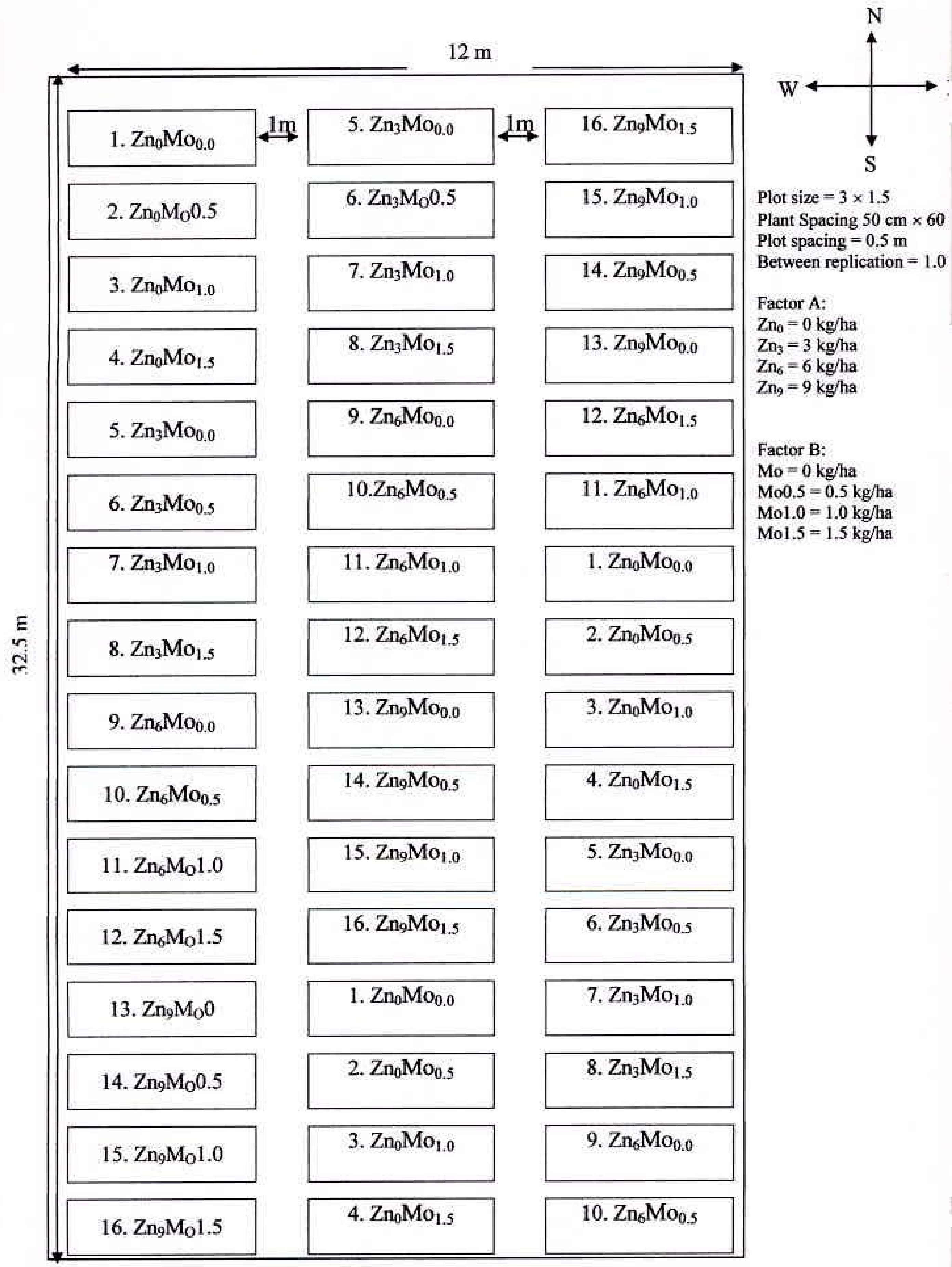


Figure 6: Field layout of two factors experiment in the Randomized Complete Block Design (RCBD)

3.6.1 Fertilizer application

The zinc form in the of zinc sulphate ($ZnSO_4.7H_2O$) and molybdenum in the form of sodium molybdate ($Na_2MoO_4.2H_2O$) were properly applied to 16 plots under 3 replications as per design of the experiment. The fertilizers were mixed well with the soil by spading.

3.6.2 Uprooting and transplanting of seedlings

Healthy and disease free uniform sized 35 days old seedlings were uprooted from the seedbeds and transplanted in the main field with the spacing of line to line 60 cm and plant to plant 50 cm in the afternoon on 23 December 2008. The seedbed was watered before uprooting the seedlings so as to minimize the damage of roots. The seedlings were watered immediately after transplanting. Some seedlings were also transplanted contiguous to the experimental field to be used for gap fillings.

3.7 Intercultural operations

Intercultural operations were performed as and when necessary throughout the growth period of the crop. Side buds and matured dry leaves were removed at the time of fertilizers application. The plants were supported by sticks. Weeding and irrigation was done as and when necessary.

3.7.1 Weeding and mulching

Weeding was done three times after transplanting to keep the crop free from weeds and mulching was done by breaking the crust of the soil for easy aeration and to conserve soil moisture after irrigation.

3.7.2 Irrigation and drainage

The young seedlings in the field were irrigated just after transplanting. Irrigation was provided by a wateringcan and or hose pump when needed throughout the growing time mainly after top dressing and after weeding. At this time care was taken so that irrigated water could not pass from one plot to another. During every irrigation, the soil was made saturated with water. After rainfall, excess water was drained when necessary.

3.7.3 Protection of plants

Against the soil born insect preventive measure was taken. For the prevention of fruit borer, Ripcord @ 1ml/ha were applied three times at an interval of 10days starting soon after the appearance of infestation. There was no remarkable attack of disease in the crop field.

3.8 Harvesting

Fruits were harvested at full maturity stages. Harvesting was done 7 March, 2009 and 12 March, 2009.

3.9 Sampling of fruits

Fruits were harvested in the morning. The collected fruits were carried in gunny bags and then half of the collected samples were immediately transferred to the storage rooms and the rest were in the laboratory for chemical analyses. Proper care was taken while harvesting and handling to avoid any mechanical injury.

3.10 Storage of samples

The storage room was the practical classroom of the Department of Soil Science, Sher-e- bangla Agricultural University, Dhaka. The fruits were stored in a safe place of the room. The room was well ventilated with four windows and two exhaust fans. The temperature and relative humidity of the storage room was recorded by a digital temperature-humidity meter.

3.11 Data collection

After the collection of fruit samples the following physical and chemical characteristics/parameters were analyzed in the different laboratories:

3.11.1 Physical characteristics

- Plant height
- Number of leaf
- Number branch
- Number of flower cluster
- Number of fruit

- Weight of single fruit
- Yield (t/ha)

3.11.2 Chemical characteristics

- Zinc content
- Zinc uptake
- Molybdenum content
- Molybdenum uptake
- Vitamin-A content
- Yield of Vitamin-A
- Vitamin-C content
- Yield of Vitamin-C

3.12 Methods of measuring different parameters

3.12.1 Plant height

Plant height was measured from the sample plants in cm from the ground level to the tip of the longest stem mean value was calculated. Plant height was recorded at 15 days interval starting from 20 days of planting up to 65 days to observe the growth rate of plants. Finally, the plant height was recorded at harvest.

3.12.2 Number of Leaf/plant

The leaves were counted from selected plants. The average number of leaf was calculated. Data were recorded as the average of 05 plant selected at random from the inner rows of each plot during harvest.

3.12.3 Number of branches/plant

The branches were counted from selected plants. The average number of branches was calculated. Data were recorded as the average of 05 plant selected at random from the inner rows of each plot during harvest.

3.12.4 Number of flower cluster /plant

Selected plants from each plot was counted and the mean number was expressed on plant^{-1} basis. The average number of flower cluster was calculated. Data were recorded as the average of 05 plant selected at random from the inner rows of each plot during harvest.

3.12.5 Number of flower /plant

Selected plants from each plot was counted and the mean number was expressed on plant^{-1} basis. The average number of flower was calculated. Data were recorded as the average of 05 plant selected at random from the inner rows of each plot during harvest.

3.12.6 Number of fruit /plant

Selected plants from each plot was counted and the mean number was expressed on plant^{-1} basis. The average number of fruit was calculated. Data were recorded as the average of 05 plant selected at random from the inner rows of each plot during harvest.

3.12.7 Weight of single fruit (g)

After harvesting five plants were randomly selected from each unit plot. Five single fruit were weighed in an electric balance and their average was considered as the single fruit weight and expressed in gram (g).

3.12.8 Yield of tomato per plot (kg)

Tomato fruits were collected from the five plants. Then with a simple balance tomato fruits weight were taken in kilogram (kg) from each unit plot separately. Data were recorded as the average of 05 plant selected at random from the inner rows of each plot during harvest.

3.12.9 Yield of tomato fruit per hectare (t)

Yield obtained from each unit plot was converted to get yield in tones ha^{-1}. Data were recorded as the average of 05 plant selected at random from the inner rows of each plot during harvest.

3.13 Chemical analysis of plant sample

3.13.1 Plant sample

Plant samples were collected from every individual plot for laboratory analysis at harvest. Five plants were randomly selected from each plot for recording data. After recording data roots was separated and then samples were dried in the electric oven at 70^0 C for 48 hours. After that the samples were ground in an electric grinding machine and stored for chemical analysis. The plant samples were collected by avoiding the border effect for the highest precision. For this the outer two rows and the outer plants of the middle rows were avoided.

3.13.2 Digestion of plant samples with sulphuric acid

For N determination, an amount of 0.1g plant sample was taken into a 100ml Kjeldahlflask. An amount of 1.1g catalyst mixture (K_2SO_4:$CuSO_4$. $5H_2O$; Se=100:10:1) 2ml 30% H_2O_2 and 3ml conc. H_2SO_4 were added into the flask. The flask was swirled and allowed to stand for about 10 minutes followed by heating at 200^0C. Heating was continued until the digest was clear, and colorless. After cooling, the contents were taken into a 100ml volumetric flask and the volume was made with distilled water. A blank digestion was prepared in a similar way. This digest was used for determining the nitrogen contents of plant samples.

3.13.3 Digestion of plant samples with nitric-perchloric acid mixture

An amount of 0.5g of sub-sample was taken into a dry clean 100 ml Kjeldahl flask, 10 ml of di-acid mixture (HNO_3, $HClO_4$ in the ratio of 2:1) was added and kept for few minutes. Then, the flask was heated at a temperature rising slowly to 200°C. Heating was instantly stopped as soon as the dense white fumes of $HClO_4$ occurred and after cooling, 6ml of 6NHCl were added to it. The content of the flask was boiled until they became clear and colorless. This digest was used for determining zinc and molybdenum.

3.13.4 Zinc

Zinc content in the digested plant sample was determined by atomic absorption spectophotometric method. (by Leif Petersen 2002)

3.13.5 Molybdenum

Molybdenum content in the digested plant sample was determined by atomic absorption spectophotometric method. (by Leif Petersen 2001)

3.14 Collection of soil samples

3.14.1 Soil Sample

The initial soil sample was collected randomly from different spots of the field selected for the experiment at 0-15 cm depth before the land preparation and mixed thoroughly to make a composite sample for analysis. Post harvest soil samples were collected from each plot at 0-15 cm depth on 15^{th} March, 2009. The samples were air-dried, ground and sieved through a 2mm (10 meshes) sieve and kept for analysis.

3.14.2 Soil sample analysis

The initial and post harvest soil sample were analyzed for both physical and chemical properties. The properties studied included texture, pH, bulk density, particle density, organic matter, total N, available P, exchangeable K and available S. The soil was analyzed by the following standard methods:

3.14.3 Particle size analysis

Particle size analysis of soil sample was done by hydrometer method as outlined by Day (1965) and the textural class was ascertained using USDA textural triangle.

3.14.4 Soil pH

Soil pH was determined by glass electrode pH meter in soil-water suspension having soil: water ratio of 1: 2.5 as outlined by Jackson (1958).

3.14.5 Organic carbon

Soil organic carbon was determined by wet oxidation method described by Walkley and Black (1935).

3.14.6 Organic matter

The organic matter content was determined by multiplying the percent organic carbon with Van Bemmelen factor 1.73 (Piper, 1950).

3.14.7 Total nitrogen

Total nitrogen of soil samples were estimated by Micro-Kjeldahl method where soils were digested with 30% H_2O_2 conc. H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Selenium powder in the ratio of 100: 10: 1, respectively). Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01 N H_2SO_4 (Bremner and Mulvaney, 1982).

3.14.8 Available phosphorous

Available phosphorous was extracted from the soil by shaking with 0.5 M $NaHCO_3$ solution of pH 8.5 (Olsen *et al.* 1954). The phosphorous in the extract was then determined by developing blue color using $SnCl_2$ reduction of phosphomolybdate complex. The absorbance of the molybdophosphate blue color was measured at 660 nm wave length by spectrophotometer and available P was calculated with the help of a standard curve.

3.14.9 Exchangeable potassium

Exchangeable potassium in the soil sample was extracted with 1N neutral ammonium acetate (NH_4OAC) and exchangeable potassium was determined by ammonium acetate extraction method (Black, 1965).

3.14.10 Available sulphur

Available sulphur was extracted from the soil with Ca $(H_2PO_4)_2.H_2O$ (Fox *et al.*, 1964). Sulphur in the extract was determined by the turbidimetric method as described by Hunt (1980) using a Spectrophotometer (LKB Novaspec, 4049).

3.15. Determination of edible portion of different fruits

In order to determine edible portion of fruits, total weight of whole fruit was recorded.

After processing, total weight roughage (seed, skin etc.) was recorded. Percentage of edible portion was calculated from the following formula:

$$\% \text{ Edible portion} = \frac{\text{Total weight of whole fruits (gm)} - \text{Total weight of roughage}}{\text{Total weight of whole fruits}} \times 100$$

3.15.1 Analysis of ascorbic acid

Ascorbic acid was estimated by spectrophotometric method. (by Raganna 1994)

Principle

Ascorbic acid when oxidizes form dehydroascorbic acid. Dehydroascorbic acid couples rapidly with 2, 4 dihydrophenyl hydrazine in 9N sulphuric acid solution forming a bis.-2,4 dinitrophenyl hydrazine derivatives which yield a highly stable brownish red color on treatment with 85% sulphuric acid.

3.15.2 Preparations of reagents

i) **5% metaphosphoric acid in 10% acetic acid solution:** 50g metaphosphoric acid was dissolved in distilled water then 100 ml glacial acetic acid was added to the solution and the volume was made 1000 ml with distilled water

ii) **9N sulphuric acid**: One volume of concentrated sulphuric acid was added to three volumes distilled water.

iii) **2,4-dinitrophenyl hydrazine:** 2,4–dinitrophenyl hydrazine (2 g) was dissolved in 9N sulphuric acid and then 4g thiourea was added, shaked until dissolved and the final volume was made 100 ml with 9N sulphuric acid. The mixture was filtered to remove any insoluble materials and stored at 4°C until used.

iv) **Acid washed norit:** 50g norit (Black charcoal powder) was placed in a flask and 200 ml of 10% hydrochloric acid was added to the norit. Heated to boiling and was filtered with suction. The norit cake was removed to another flask.Then 1000 ml distilled water was added and stirred thoroughly and again filtered. Finally the norit cake was transferred to a beaker and kept in an oven at 110°C-120°C until the norit become dried.

v) **Sulphuric acid 85%:** 900 ml concentrated sulphuric acid was added carefully to 100 ml cold distilled water. During the preparation the volumetric flask was kept in an ice bath.

3.15.3 Preparation of ascorbic acid standard

25 mg standard ascorbic acid (Sigma chemical co. USA) was dissolved in 25 ml of 5% metaphosphoric acid in 10% acetic acid solution (AOAC, 16th edition). The concentration was 1 mg /ml.

3.15.4 Preparation of working standard

Multiple standard preparations processed during every day analysis. From the stock standard Solutions, a series of standard containing various concentrations had been made.

1. 20 μgm/ml
2. 40 μgm/ml
3. 60 μg/ml

20 μmg/ml working standard solution: 20 μmg/ml working standard solution of ascorbic acid was prepared by pipetting 0.5 ml of the stock solution in to 25 ml volumetric flask and was made up to the mark with 5% metaphosphoric acid in 10% acetic acid solution. For norit oxidation acid-washed norit (1g) was added to 25 ml working standard solution and mixed thoroughly. After mixing, the solution was filtered through acid-washed filter paper.

40 μmg/ml working standard solution: 40 μmg / ml working standard solution of ascorbic acid was prepared by pipetting 1 ml of the stock solution in to 25 ml volumetric flask and was made up to the mark with 5% metaphosphoric acid in 10% acetic acid solution. For norit oxidation acid-washed norit (1g) was added to 25 ml working standard solution and mixed thoroughly. After mixing, the solution was filtered through acid-washed filter paper.

60 μmg/ml working standard solution: 60 μmg / ml working standard solution of ascorbic acid was prepared by pipetting 1.5 ml of the stock solution in to 25 ml volumetric flask and was made up to the mark with 5% metaphosphoric acid in 10% acetic acid solution. For norit oxidation acid-washed norit (1g) was added to 25 ml working standard solution and mixed thoroughly. After mixing, the solution was filtered through acid-washed filter paper.

3.15.5 Preparation of standard calibration curve and estimation of ascorbic acid:

The fresh fruit sample was taken and its clean by tissue then cut into small pieces and the sample was mixing together, from them, 3-5 gm sample was taken and homogenized in a morter with a pastle using 10 ml of 5% metaphosphoric acid in 10% acetic acid solution and the mixture was then filtered by suction. The extract was collected in a conical flask and 1.5 gm acid washed norit was added to it and stirred for 10 minutes. The mixture was then filtered by sintered glass filter. This extracted sample solution was become into water color. This extracted solution was made 25 ml volume by the 5 % metaphosphoric acid in

10% acetic acid solution. Then 2 ml of norit filtrate was taken in each of two test tubes and in a third test tube 2 ml norit treated standard ascorbic acid (All of different concentration like 0.5 ml for 20 μgm, 1.0 ml for 40 μgm ,2.0 ml for 80 μgm and 2.5ml for 120 μgm), 2 ml of 5% metaphosphoric acid in 10% acetic acid solution in another test tube 2 ml metaphosphoric acid solution (as blank)were taken in different test tubes which were marked. Then 0.5ml of 2,4 – dinitrophenyl hydrazine was added to each of the test tubes containing sample extract, standard ascorbic acid and blank solution. The tubes were then placed in a water bath at 60°C for 1 hours. After the end of incubation the tubes were removed and placed in a ice bath, 2.5 ml of 85% sulphuric acid was added drop wise and slowly to each test tube. All the tubes were vortexed thoroughly and carefully and left at room temperature for 30 minutes. Timing is very important to maintain throughout the analysis. The absorbance was measured at 520 nm in spectrophotometer (UV-1201, UV-VIS, Shimadzu, Japan). The reading was taken against the sample blank.The standard curve was calibrated by plotting the standard absorbance against different concentrations.

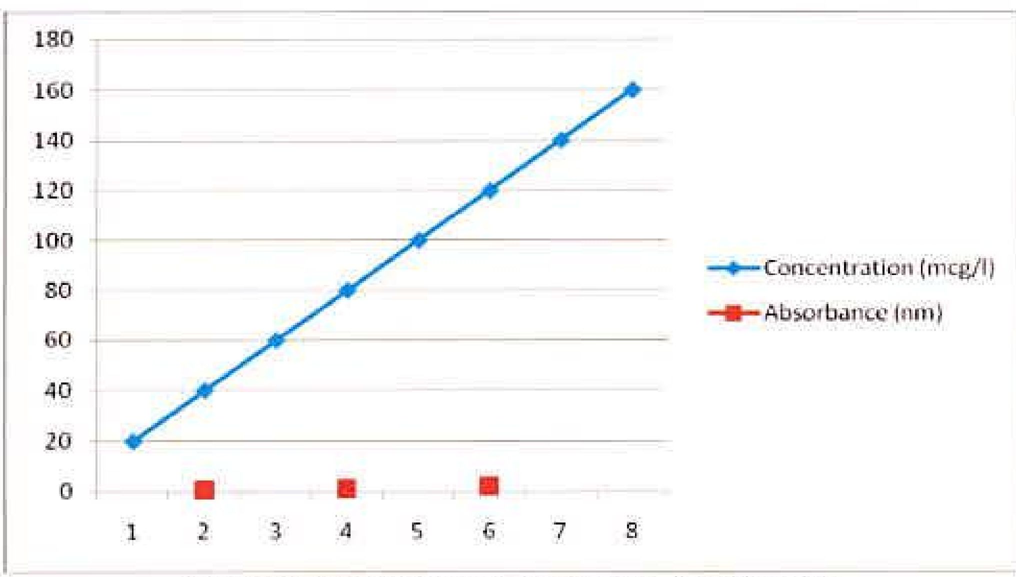


Figure 7: Standard curve for vitamin- C estimation

3.15.6 The ascorbic acid content was calculated using the following formula:

Ascorbic acid content (mg /100g) =

$$\frac{\text{Graph factor} \times \text{Absorbance of sample extract} \times \text{Final volume} \times 100}{\text{Sample extract taken for analysis} \times \text{Sample weight} \times 1000} \times 100$$

Estimation of ascorbic acid in minor fruits

1. Weigh 3 gm of sample with the balance
2. Grind the Sample using mortar and pestle along with 1-3 gm acid wash sand
3. Adding 5 ml. of 5% metaphosphoric acid in 10% acetic acid
4. The mixture had filtered by suction pump and sintered glass
5. The extract was collected in a conical flask and 1 gm of acid washed norit added to it and shaken vigorously with a magnetic stirrer
6. The mixture was then filtered by sintered glass filter
7. To make the sample 50 ml. (final volume), by metaphosphoric acid and kept overnight in a refrigerator repeatedly washing the used
8. 2 ml of norit treated sample extract, 2 ml of std from all different concentration & 2 ml metaphosphoric acid as blank were taken in different test tube
9. Then 0.5 ml of 2,4 di-nitro phenyl hydrazine was added to each test tube
10. The tubes were then placed in a water bath at 60 C for 60 minutes
11. After the incubation, the tubes were removed and placed in an ice bath
12. 2.5 ml of 85% Sulfuric acid was added drop wise slowly & carefully to each test tube and kept it for 30 minutes and then ready for reading

Figure 8: Flow chart of the sample preparation & standard for reading

3.16 Procedures for analysis of caroteniod from fruits sample

3.16.1 Preparation

Ten percent bleach solution was prepared with 100 ml of chlorox (5.25% solution of Sodium Hypochlorite) and 900 ml of boiled water. This solution will be used to rinse utensils and surfaces to prevent any microbial contamination.(USNAS,1990). Good quality fruits were chosen. Then they were washed thoroughly and sorted according to size. Weight was taken before chopping. After chopping the sliced samples were homogenized well. From the sample appropriate weight of sample were taken for extraction.

3.16.2 Materials

Glassware: Small mortar and pestle
250 ml separatory funnel
Buchner funnel
Vacuum flask
Filter paper
2 glass cylinders (250ml) one for acetone and one for Petroleum ether
One 25ml glass volumetric flask
One small glass funnel with filter paper for use with the Volumetric flask

Chemicals: Acetone
Petroleum ether
Butylated Hydroxy Toluene (BHT)

Miscellaneous: Glass transfer pipettes
Gloves
Kim wipes
Weighing paper

3.16.3 Set-up

1. Acetone was placed in the refrigerator (4°C) for two hours before beginning homogenization procedure.
2. The vacuum flask was wrapped. It was used to collect the petroleum ether extract in foil.
3. A representative sample of minor fruit (5-10 g) was taken, protected from light (inside a closed drawer).
4. A solution of 1mg/ml. BHT in acetone was prepared (10 ml. total volume). The vial was wrapped in the foil and labeled (w/date). This solution is good for a few weeks.

3.16.4 Analysis of total carotenoid

Extraction carotenoids concentration from fruits

Total carotenoid concentration of the minor fruit samples were determined by spectrophotometry method at 450 nm (USNAS 1990).

- 5-10 g of the sample was taken in a mortar and pestle and homogenized until mashed and well mixed.
- Three samples were weighed; each weighing 0.5-5.0 g from the mashed sample from the step one, and the weight was recorded. Carefully the weighed samples were transferred to 3 small mortar and pestles. Then covered in foil and 2 and 3 no. samples were placed in the refrigerator.
- The remaining mashed sample was placed from step 1 back in the storage bag it was taken from initially and stored at –20° C.
- For each sample beginning with sample 1, the following procedures were followed:

- 25 ml of cold acetone and 100μL of the 1 mg/ml solution of BHT in acetone was added.Then homogenized carefully for about 3 minutes by hand.
- The homogenate was carefully transferred to a Buchner funnel under vacuum using a glass transfer pipette and then the acetone extract was

collected into the vacuum flask. The mortar and pestle was washed with small amount of acetone and added to the Buchner funnel to filter. More acetone was added to the Buchner funnel until the acetone was colorless.

- 20 ml of petroleum ether was added to the separatory funnel. The acetone extract was added and the vacuum flask was rinsed with a few ml.s of acetone.
- 7.150 ml of deionized water was slowly added to the separatory funnel, allowing the water to gently flow down the inside of the funnel (If the water is added too quickly an emulsion will be formed.) The layers were then allowed to separate. Then the lower aqueous layer was discarded.
- The petroleum ether extract was washed 3-4 more times with 100 ml of deionized water until the water was completely clear to remove residual acetone. The lower phase was discarded completely.
- The petroleum ether extract was collected through a funnel that contains a small amount of anhydrous sodium sulphate, into a 25 ml volumetric flask wrapped in foil. The separatory funnel was rinsed with small amount (2ml) of petroleum ether using a transfer pipette. Then the solution was brought to volume (25 ml) using petroleum ether. The flask was capped and gently mixed.

3.16.5 Recording absorbance of the extracted solution

The absorbance was read at 450 nm immediately using petroleum ether to zero the spectrophotometer. After adjusting the zero spectrophotometer once with petroleum ether checked again to see whether the reading for petroleum ether remains stable at zero. The absorbance of the sample was recorded at 450 nm.

The total carotenoid concentrated was calculated using the formula below:

$$\text{Total carotenoid content } (\mu g/g) \quad \frac{A \times \text{volume ml}) \times 10^4}{A^{1\%\text{-cm}} \times \text{sample weight (g)}}$$

A = Absorbance at 450 nm

Volume=Total volume of extract (25 or 50 ml)

$A^{1\%\text{-cm}}$=Absorption coefficient of β-carotene in petroleum ether (2592)

3.16.6 **Precaution are taken during analysis of carotenoids**

- ❖ The samples were protected from exposure to light, oxygen and heat.
- ❖ The analysis was completed in one session as quickly as possible to prevent losses of carotenoid from exposure to air, light and heat.
- ❖ All procedures were carried out in dim light; containers containing carotenoid solutions were wrapped in foil as added protection.

3.17 Statistical analysis

The data obtained from the experiment were analyzed statistically using MSTAT computer package program to find out the significance of the difference among the treatments. The mean values of all the treatment were calculated and analysis of variances for all the characters was performed by the 'F' (variance ratio) test. The significance of the differences among the pairs of treatment means was estimated by the Duncan Multiple Range Test (DMRT) at 1% and 5% level of probability (Gomez and Gomez, 1984) for the interpretation of results.

Chapter IV
Results and Discussion

RESULTS AND DISCUSSION

To determine the effect of different levels of zinc and molybdenum on yield and yield contributing characters of tomato as well as the nutrient content and their uptake by plants and fruits the present experiment was conducted. Data on different characters were recorded and analyzed to find out the effects of zinc and molybdenum. The analyses of variance (ANOVA) of the data on different components are given in Appendix II-IV. The results have been presented and discussed, and possible explanations have been given under the following headings:

4.1 Yield and yield contributing character of tomato

Yield contributing characters such as plant height, number of leaf, number of branch, number of flower cluster per plant, number of flower per plant, number of fruits per plant, weight of single fruits per plant and yield per hectare were recorded.

4.1.1 Plant height

Plant height varied significantly due to the application of zinc in tomato under the present trial (Appendix II). With increasing the level of zinc, plant height increased significantly up to Zn_6 (6 kg Zn/ha) and the maximum pant height was 63.63 cm and the lowest was obtained from the control (55.33 cm). Probably all micro and macro nutrients for 6 kg Zn/ha influced the favorable condition for growth of tomato plant and the ultimate results is the tallest plant, whereas above this level of zinc is not beneficial to the growth of plant. Mondal *et al.* (1992) found that plant height of tomato was increased upto the highest level of zinc. Similar results was reported by Dube *et al.* (2003).

Different levels of molybdenum showed statistically significant differences for plant height (Appendix II). With increasing the doses of molybdenum, the plant height increased significantly up to $Mo_{1.0}$ (1.0 kg Mo/ha). However the maximum plant height was obtained from $Mo_{1.0}$ (82.70 cm) and the lowest from the $Mo_{0.0}$ (57.55 cm) With increasing the level of molybdenum plant height also increases but the differences was not significant at highest level.

Interaction effect was also recorded between zinc and molybdenum in consideration of plant height under the present experiment and found the significant variation (Appendix II). The maximum plant height (66.80 cm) was recorded from treatment combination $Zn_9Mo_{1.0}$ (9 kg Zn/ha + 1.0 kg Mo/ha), while the minimum plant height (53.78 cm) was recorded from treatment combination Zn_0Mo_0 (Table 5). These results revealed that higher dose of zinc and molybdenum increased the plant height.

4.1.2 Number of leaf

A statistically significant variation was recorded for the effect of zinc in terms of number of leaf (Appendix II). The maximum number of leaf (25.27) was recorded from Zn_6 treatment consisting of 6 kg Zn/ha which was statistically identical (23.77) with Zn_9 treatment as 9 kg Zn/ha and the minimum number of leaf (20.72) was recorded from Zn_0 treatment i.e. control condition.

In case of different levels of molybdenum, statistically significant variation was found for the number of leaf (Appendix II). The maximum number of leaf (25.16) was recorded from $Mo_{1.0}$ treatment comprising of 1.0 kg Mo/ha which was statistically identical (24.92) with $Mo_{1.5}$ treatment as of 1.5 kg Mo/ha and $Mo_{0.5}$ treatment as 0.5 kg Mo/ha (Table 4), while the minimum number of leaf (19.94) was recorded from Mo_0 treatment i.e. control condition under the present trial. With increasing the level of molybdenum number of leaf also increases but the differences was not significant at highest level.

Significant effect of combined application of different doses of zinc and molybdenum on number of leaf showed a statiscally significant variation (Appendix II). The maximum number of leaf (27.44) was recorded from treatment combination $Zn_6Mo_{1.0}$ 6 kg Zn/ha + 1.0 kg Mo/ha, while the minimum number of leaf (17.67) was recorded from treatment combination Zn_0Mo_0 i.e. without any zinc and molybdenum (Table 5). These results revealed that higher dose of zinc and molybdenum increased the number of leaf.

4.1.3 Number of branch

In terms of number of branch a statistically significant variation was recorded for the effect of zinc under present trial (Appendix II). The maximum number of branch (7.85) was recorded from Zn_6 treatment consisting of 6 kg Zn/ha which was statistically identical (7.71) with Zn_9 treatment as 9 kg Zn/ha and the minimum number of branch (6.55) was recorded from Zn_0 treatment i.e. control condition. Similar result was reported by Yadav *et al.* (2001).

Different levels of molybdenum showed statistically significant differences for number of branch (Appendix II). The maximum number of branch (7.91) was recorded from $Mo_{1.0}$ treatment comprising of 1.0 kg Mo/ha which was statistically identical (7.91) with $Mo_{1.5}$, treatment as of 1.5 kg Mo/ha and $Mo_{0.5}$ treatment as 0.5 kg Mo/ha (Table 4), while the minimum number of branch (6.24) was recorded from Mo_0 treatment i.e. control condition under the present trial. With increasing level of molybdenum number of branch also increases but the differences was not significant at highest level.

The effect of integrated use of zinc and molybdenum on number of branch of tomato is presented in table 5. The maximum number of branch (8.44) was recorded from treatment combination $Zn_6Mo_{1.0}$ 6 kg Zn/ha + 1.0 kg Mo/ha, while the minimum number of branch (5.10) was recorded from treatment combination Zn_0Mo_0 i.e. without any zinc and molybdenum (Table 5). These results revealed that higher dose of zinc and molybdenum increased the number of branch.

4.1.4 Number of flower cluster per plant

In case of flower cluster of plant significant differences were found for the effect of zinc under present trial (Appendix II). The maximum number of flower cluster (23.08) per plant was recorded Zn_6 treatment which was statistically similar (22.33) with Zn_9 treatment (Table 4) and the minimum (16.42) was recorded under Zn_0 treatment which was closely (20.85) followed by Zn_3 treatment. Application of 6 kg Zn/ha ensured the favorable condition for growth of tomato plant and the ultimate results is the maximum number of flower cluster per plant. This is an agreement with Rahman *et al.* (1996).

The effect of different levels of molybdenum on the number of flower cluster per plant varied significantly (Appendix II). The maximum number of flower cluster (22.38) per plant was recorded from Mo_0 treatment which was closely (22.18) followed by Mo_0 treatment (Table 4). On other hand the minimum number of flower cluster (17.70) per plant was recorded from Mo_0 treatment under the present trial. With increasing level of molybdenum, plant growth increases and the number of flower cluster per plant also increased.

Combined effect of different doses of zinc and molybdenum on flower cluster per plant showed a statistically significant variation (Appendix II). The maximum number of flower cluster (25.70) per plant was recorded from treatment combination $Zn_6Mo_{1.0}$. On the other hand the minimum number of flower cluster (14.20) per plant was recorded from treatment combination Zn_0Mo_0 (Table 5). These results revealed that combined higher dose of zinc and molybdenum is essential for attaining better growth and the ultimate results was the highest number of flower cluster per plant.

Table 4: Effect of zinc and molybdenum on plant height, number of leaf, number of branch and number of flower cluster of tomato

Treatment	Plant height/plant (cm)	Number of leaf/plant (no.)	Number of branch/plant (no.)	Number of flower cluster/plant (no.)
Zinc				
Zn_0	55.33c	20.72c	6.55b	16.42c
Zn_3	60.24b	23.22b	7.58a	20.85b
Zn_6	63.63a	25.27a	7.85a	23.08a
Zn_9	63.04a	23.77b	7.71a	22.33a
$SE_{(0.05)}$	0.6904	0.4958	0.09399	0.4301
CV(%)	3.93	9.57	4.39	7.21
Molybdenum				
Mo_0	57.55b	19.94c	6.24b	17.70c
$Mo_{0.5}$	60.46a	22.97b	7.63a	20.43b
$Mo_{1.0}$	62.70a	25.16a	7.91a	22.38a
$Mo_{1.5}$	62.53a	24.92a	7.92a	22.18a
$SE_{(0.05)}$	0.7972	0.5725	0.1085	0.4967
CV(%)	3.93	9.57	4.39	7.21

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

Zn_0: 0 kg Zn/ha Mo_0 : 0 kg Mo/ha
Zn_3: 3 kg Zn/ha $Mo_{0.5}$: 0.5 kg Mo/ha
Zn_6: 6 kg Zn/ha $Mo_{1.0}$: 1.0 kg Mo/ha
Zn_9: 9 kg Zn/ha $Mo_{1.5}$: 1.5 kg Mo/ha

Table 5: Interaction effect of zinc and molybdenum on plant height, number of leaf, number of branch and number of flower cluster of tomato

Treatment combination	Plant height/plant (cm)	Number of leaf/plant (no.)	Number of branch/plant (no.)	Number of flower cluster/plant (no.)
Zn_0Mo_0	53.78i	17.67h	5.10e	14.20h
$Zn_0Mo_{0.5}$	54.66hi	20.22gh	6.67d	16.70g
$Zn_0Mo_{1.0}$	56.22g-i	22.20d-g	7.11cd	17.20fg
$Zn_0Mo_{1.5}$	56.67g-i	22.78c-g	7.33c	17.60fg
Zn_3Mo_0	57.30f-i	20.10gh	6.55d	17.70fg
$Zn_3Mo_{0.5}$	59.52d-g	22.67c-g	7.63bc	20.70c-e
$Zn_3Mo_{1.0}$	61.33b-f	24.22a-e	8.00ab	21.90b-e
$Zn_3Mo_{1.5}$	62.80a-e	25.89a-c	8.11ab	23.10a-c
Zn_6Mo_0	58.67e-h	21.44e-g	6.66d	19.60d-f
$Zn_6Mo_{0.5}$	63.66a-d	25.33a-d	8.20ab	22.33b-d
$Zn_6Mo_{1.0}$	66.44a	27.44a	8.44a	25.70a
$Zn_6Mo_{1.5}$	65.77ab	26.89ab	8.11ab	24.70ab
Zn_9Mo_0	60.44c-g	20.55f-h	6.66d	19.30e-g
$Zn_9Mo_{0.5}$	64.00a-d	23.66bc-f	7.98ab	22.00bc-e
$Zn_9Mo_{1.0}$	66.80a	26.77ab	8.10ab	24.70ab
$Zn_9Mo_{1.5}$	64.90a-c	24.11bc-e	8.11ab	23.33a-c
$SE_{(0.05)}$	1.381	0.9916	0.1880	0.8602
CV(%)	3.93	9.57	4.39	7.21

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

Zn_0 : 0 kg Zn/ha Mo_0 : 0 kg Mo/ha

Zn_3 : 3 kg Zn/ha $Mo_{0.5}$: 0.5 kg Mo/ha

Zn_6 : 6 kg Zn/ha $Mo_{1.0}$: 1.0 kg Mo/ha

Zn_9 : 9 kg Zn/ha $Mo_{1.5}$: 1.5 kg Mo/ha

4.1.5 Number of flower per plant

Number of flower per plant varied significantly due to the application of different levels of zinc in tomato under the present experiment (Appendix III). The maximum number of flower (114.1) per plant was recorded from Zn_6 treatment which was statistically identical (113.6) with Zn_9 treatment (Table 6) and the minimum number of flower (92.25) per plant was recorded from Zn_0 treatment which was statistically identical (102.6) with Zn_3 treatment.

Application of molybdenum fertilizers at different doses showed a significant variation (Appendix III). The maximum number of flower (111.8) per plant was recorded from Mo_0 which was closely (111.3) followed by $Mo_{1.5}$ treatment (Table 6). On the other hand the minimum number of flower (93.68) per plant was recorded from Mo_0 treatment which was statistically identical (105.7) with $Mo_{0.5}$ treatment under the present trial. With increasing the level of molybdenum, plant growth and number of flower per plant were increased and the variations due to different level of nutrient were also statistically significant.

Significant effect of combined application of different doses of zinc and molybdenum on number of flower showed a statistically significant variation (Appendix III). The maximum number of flower (123.7) per plant was recorded from treatment combination $Zn_6Mo_{1.0}$ On the other hand the minimum number of flower (82.00) per plant was recorded from Zn_0Mo_0 (Table 7). These results revealed that higher dose of zinc and molybdenum is influenced the nutrient for attaining better growth and the ultimate results the highest number of flower per plant.

4.1.6 Number of fruits per plant

Number of fruits per plant varied significantly due to different level of zinc in tomato under the present experiment (Appendix III). The maximum number of fruits (44.17) per plant was recorded from Zn_6 treatment which was statistically similar (42.50) with Zn_9 treatment (Table 6) and the minimum number of fruits (33.83) per plant was recorded from Zn_0 treatment which was statistically identical (39.83) with Zn_3 treatment. Similar result was reported by Yadav *et al.* (2001).

Different levels of molybdenum showed statistically significant differences for number of fruits per plant (Appendix III). The maximum number of fruits (42.49) per plant was recorded from $Mo_{1.0}$ treatment which was statistically similar (42.25) with $Mo_{1.5}$ treatment (Table 6). On the other hand the minimum number of fruits (34.75) per plant was recorded from Mo_0 treatment which was increase (40.83) followed by $Mo_{0.5}$ treatment under the present experiment. With increasing levels of molybdenum, plant growth was increased and produced maximum number of flower and fruit per cluster as well as the number of fruits per plant.

Integrated effect of zinc and molybdenum showed a significant variations in respect of number of fruits of tomato (Appendix III). The maximum number of fruits (48.67) per plant was recorded from $Zn_6Mo_{1.0}$. On the other hand the minimum number of fruits (30.67) per plant was recorded from Zn_0Mo_0 (Table 7). These results revealed that higher dose of zinc and molybdenum influenced the nutrient for attaining better growth and the ultimate results was maximum number of flower and fruit per cluster.

4.1.7 Weight of fruits per plant

Weight of single fruit per plant varied significantly due to the application of zinc in tomato under the present experiment (Appendix III). The maximum single weight of fruit (35.17 gm) per plant was recorded from Zn_6 treatment which was statistically similar (33.38 gm) with Zn_9 treatment (Table 6) and the minimum single fruit weight (32.06 gm) per plant was recorded from Zn_0 treatment which was statistically identical (39.8 3 gm) with Zn_3 treatment. Similar result was reported by Dube *et al.* (2003).

Different levels of molybdenum showed statistically significant differences for single fruit weight per plant (Appendix III). The maximum single fruit weight (34.95 gm) per plant was recorded from $Mo_{1.0}$ treatment which was statistically similar (34.47 gm) with $Mo_{1.5}$ treatment (Table 6). On the other hand the minimum single fruit weight (30.83 gm) per plant was recorded from Mo_0 treatment which was gradually increased (33.32gm) with the increasing of molybdenum. With the increasing levels of molybdenum plant growth was increased and that maximize the number of flower and fruit per cluster as well as the single fruit weight per plant.

Combined effect of different doses of zinc and molybdenum on weight of single fruit per plant showed a statistically significant variation (Appendix III). The maximum single weight of fruits (37.75 gm) per plant was recorded from $Zn_6Mo_{1.0}$. On the other hand the minimum weight of fruit (29.31 gm) per plant was recorded from Zn_0Mo_0 (Table 7). These results revealed that higher dose of zinc and molybdenum is Influential nutrient for attaining better growth and the ultimate results was desirable growth with maximum number of flower and single weight of fruit per plant.

4.1.8 Yield per hectare

Yield per hectare varied significantly due to the application of zinc in tomato under the present experiment (Appendix III). The maximum yield (44.26 t/ha) was recorded from Zn_6 treatment which was closely (44.06 t/ha) followed by Zn_9 treatment (Table 4.3) and the minimum yield (34.66 tonnes) was recorded from Zn_0 treatment which was closely (38.66 t/ha) followed by Zn_3 treatment. Cakmak *et al.* (1996) reported that increasing levels of zinc increased the fresh weight of tomato fruit and the ultimate result is the highest yield per hectare of tomato.

Application of different levels of molybdenum showed statistically significant differences in yield of tomato (Appendix III). The maximum yield (41.46 t/ha) was recorded from $Mo_{1.0}$ treatment which was statistically similar (41.00 t/ha) with $Mo_{1.5}$ treatment (Table 6). On the other hand the minimum yield (37.40 t/ha) was recorded from Mo_0 treatment which was closely (39.62 t/ha) followed by $Mo_{0.5}$. With the increasing level of molybdenum plant growth increases and which was produced maximum number of flower, fruit per cluster weight of fruits per plant as well as the yield per hectare. Jain (1973) reported that yield per hectare was increased significantly as molybdenum increased.

Interaction effect was also recorded between zinc and molybdenum in consideration of yield per hectare under the present experiment and found statistically significant variation (Appendix III). The maximum yield (47.06 t/ha) was recorded from $Zn_6Mo_{1.0}$ (Figure 1 and appendix V). On the other hand the minimum yield (31.11 t/ha) was recorded from Zn_0Mo_0 (Table 7).

Table 6: Effect of zinc and molybdenum on number of flower, number of fruit, weight of single fruit and yield of tomato

Treatment	Number of flower/plant (no.)	Number of fruit/plant (no.)	weight of single fruit/plant (gm)	Yield (t/ha)
Zinc				
Zn_0	92.25c	33.83c	32.06b	34.66c
Zn_3	102.6b	39.83b	31.95b	38.56b
Zn_6	114.1a	44.17a	35.17a	44.26a
Zn_9	113.6a	42.50a	33.38ab	44.06a
$SE_{(0.05)}$	1.566	0.7280	0.7337	1.58
CV(%)	5.14	7.21	7.67	7.01
Molybdenum				
Mo_0	93.68c	34.75b	30.83b	37.4b
$Mo_{0.5}$	105.7b	40.83a	33.32a	39.62ab
$Mo_{1.0}$	111.8a	42.49a	34.95a	41.46a
$Mo_{1.5}$	111.3a	42.25a	34.47a	41.00a
$SE_{(0.05)}$	1.808	0.8406	0.8472	1.331
CV(%)	5.14	7.21	7.67	7.01

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

Zn_0: 0 kg Zn/ha — Mo_0: 0 kg Mo/ha

Zn_3: 3 kg Zn/ha — $Mo_{0.5}$: 0.5 kg Mo/ha

Zn_6: 6 kg Zn/ha — $Mo_{1.0}$: 1.0 kg Mo/ha

Zn_9: 9 kg Zn/ha — $Mo_{1.5}$: 1.5 kg Mo/ha

Table 7: Interaction effect of zinc and molybdenum on number of flower, number of fruit, weight of single fruit and yield of tomato

Treatment combination	Number of flower/plant (no.)	Number of fruit/plant (no.)	Weight of single fruit/plant (gm)	Yield (t/ha)
Zn_0Mo_0	82.00g	30.67f	29.31d	31.11e
$Zn_0Mo_{0.5}$	92.67f	34.33ef	32.17b-d	35.31de
$Zn_0Mo_{1.0}$	96.67ef	35.00ef	32.90a-d	35.8de
$Zn_0Mo_{1.5}$	97.67ef	35.30e	33.84a-d	36.44d
Zn_3Mo_0	94.00ef	35.67e	30.81cd	37.75cd
$Zn_3Mo_{0.5}$	101.7d-f	40.67cd	32.14bcd	38.04cd
$Zn_3Mo_{1.0}$	104.0c-e	41.30c	32.54b-d	38.84b-d
$Zn_3Mo_{1.5}$	110.7b-d	41.70c	32.33b-d	29.55b-d
Zn_6Mo_0	101.0d-f	36.00e	31.35b-d	40.48b-d
$Zn_6Mo_{0.5}$	112.3bc	44.67a-c	35.29a-c	42.44a-c
$Zn_6Mo_{1.0}$	123.0a	48.67a	36.75a	47.06a
$Zn_6Mo_{1.5}$	120.0ab	47.33ab	36.30ab	46.07a
Zn_9Mo_0	97.70ef	37.67de	31.87b-d	40.26b-d
$Zn_9Mo_{0.5}$	116.0ab	43.67bc	33.67a-d	42.68a-c
$Zn_9Mo_{1.0}$	123.7a	45.00a-c	34.67a-d	44.13ab
$Zn_9Mo_{1.5}$	117.0ab	44.67a-c	33.33a-d	41.97a-c
$SE_{(0.05)}$	3.132	1.456	1.467	3.6238
CV(%)	5.14	7.21	7.67	7.01

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

Zn_0: 0 kg Zn/ha Mo_0 : 0 kg Mo/ha

Zn_3: 3 kg Zn/ha $Mo_{0.5}$: 0.5 kg Mo/ha

Zn_6: 6 kg Zn/ha $Mo_{1.0}$: 1.0 kg Mo/ha

Zn_9: 9 kg Zn/ha $Mo_{1.5}$: 1.5 kg Mo/ha

4.2 Quality contributing characters

4.2.1 Vitamin-A content

The amount of vitamin-A content in tomato were varied due to application of different doses of zinc fertilizers (Appendix IV). Considering all doses, plant gave highest vitamin-A (6444 μg/100g) when they were fertilized with 9 Kg Zn ha^{-1} and the lowest vitamin-A content (5028.0 μg/100g) was found in the control treatment (Table 8). These results represented that higher doses of zinc increased vitamin-A content in tomato fruit. Similar result was reported by Dube *et al.* (2003).

Molybdenum also had significant effect on vitamin-A content (Appendix IV). Among all the doses, highest vitamin-A (6047.0 μg/100g) was found when the plants were applied 1.5 kg Mo ha^{-1} and the lowest (5599.0 μg/100g) from control (Table 8). These results represented that higher doses of Mo slightly increased the vitamin-A content in fruit. This results also have the similarity with Navez *et al.* (2004).

Combined effect of different doses of zinc and molybdenum on vitamin-A showed a statistically significant (appendix IV). The highest value (6578.0 μg/100g) was obtained when the plants were fertilized with 9 kg Zn ha^{-1}+1.0kgMo ha^{-1} and the lowest one (4862.0 μg/100g) from control (Table 9). These results presented that the combined effect of zinc and molybdenum slightly increased the vitamin-A content in tomato fruit.

4.2.2 Yield of Vitamin-A

Yield per hectare varied significantly due to the application of zinc in tomato under the present experiment (Table 10). The maximum yield of vitamin-A (2839.23 g/ha) was recorded from Zn_9 treatment which was statistically identical with (2838.84 g/ha) Zn_6 treatment (Table 10) and the minimum yield (1742.70 g/ha) was recorded from Zn_0 treatment which was closely (2109.60 g/ha) followed by Zn_3 treatment.

Different levels of molybdenum showed statistically significant differences for yield per hectare per plant (Table 10). The maximum yield of vitamin-A (2479.27 g/ha) was recorded from $Mo_{1.5}$ treatment which was statistically similar (2470.19 g/ha) with $Mo_{1.0}$ treatment (Table 11). On the other hand, the minimum yield (2094.02g/ha) was recorded from Mo_0 treatment which was closely (2281.32 g/ha) followed by $Mo_{0.5}$ treatment under the present experiment. With increasing level of molybdenum, yield of vitamin-A also increased .

Interaction effect was also recorded between zinc and molybdenum in consideration of yield of vitamin-A per hectare under the present experiment and found statistically significant variation (Table 11).The maximum yield of vitamin-A (3090.90 g/ha) was recorded from $Zn_6Mo_{1.0}$. Next to, the minimum yield (1512.57 g/ha) per hectare was recorded from treatment combination Zn_0Mo_0 (Table 11).

4.2.3 Vitamin-C content

The effect of different levels of zinc showed a significant variation of vitamin-C in tomato fruit (Appendix IV). Considering all doses, highest vitamin-C (17.52 mg100g^{-1}) was recorded when the soil was fertilized with 6 Kg Zn/ha (Figure 2 and appendix V) and the lowest vitamin-C content (12.26 mg100g^{-1}) was found in the control treatment (Table 8). These results indicated that higher doses of zinc increased vitamin-C content in tomato fruit.

Molybdenum also had significant effect on vitamin-C content (Appendix IV). Among all the doses, highest vitamin-C (16.24 mg 100g^{-1}) was recorded when the plants were applied 1.5kg Mo ha^{-1} (Figure 3 and appendix V) and the lowest (14.04 mg100g^{-1}) from control (Table 8). These results represented that higher doses of Mo slightly increased the vitamin-C content in fruit.

The interaction effect of zinc and molybdenum on vitamin-C content was significant (appendix IV). The highest value (18.61 mg $100g^{-1}$) was recorded when the plants were fertilized with 6 kg Zn ha^{-1}+1.5 kg Mo ha^{-1} and the lowest one (11.50 mg$100g^{-1}$) from control (Table 9). These results indicated that the combined effect of zinc and molybdenum slightly increased the vitamin-C content in tomato fruit (Figure 4 and appendix V).

4.2.4 Yield of Vitamin-C

Yield per hectare varied significantly due to the application of zinc in tomato (Table 10). The maximum yield of vitamin-C (7617.97 g/ha) was recorded from Zn_9 treatment which was closely (7754.35 g/ha) followed by Zn_6 treatment (Table 10) and the minimum yield (4249.32 g/ha) was recorded from Zn_0 treatment which was closely (5614.34 g/ha) followed by Zn_3 treatment.

Different levels of molybdenum showed statistically significant differences for yield per hectare (Table 10). The maximum yield of vitamin-C (6687.50 g/ha) was recorded from $Mo_{1.0}$ treatment, which was statistically similar (6658.40 g/ha) with $Mo_{1.5}$ treatment (Table 10). Further more, the minimum yield (5250.96 g/ha) was recorded from Mo_0 treatment which was closely (6030.16 g/ha) followed by $Mo_{0.5}$. With the increasing level of molybdenum, yield of vitamin-C also increased.

Interaction effect of zinc and molybdenum on yield of vitamin-C was found significant (Table 11). The maximum yield of vitamin-C (8757.86 g/ha) was recorded from $Zn_6Mo_{1.0}$. On the other hand the minimum yield (3577.65 g/ha) was recorded from treatment combination Zn_0Mo_0 (Table 11).

4.3 Chemical contributing characters

4.3.1 Zinc content

Zinc uptake by shoot showed statistically significant variations due to the effect of different levels of zinc (Appendix IV). Considering all doses, highest zinc was found (361.5 ppm) when they were fertilized with 6 Kg Zn/ha and the lowest zinc content (190.3 ppm) was found in the control treatment (Table 8). These results represented that higher doses of zinc increased the zinc content in tomato shoot.

A statistically significant difference of zinc was recorded in shoot for different level of molybdenum (Appendix IV). Among all the doses, highest zinc (290.3 ppm) was found when the plants were applied the1.0 kg Mo/ha and the lowest (266.5 ppm) from control (Table 8). These results represented that higher doses of molybdenum slightly increased the zinc content in tomato shoot.

The interaction effect of zinc and molybdenum on zinc content was significant (appendix IV). The highest value (378 ppm) was recorded when the plants were fertilized with 6 kg Zn ha^{-1}+1.5 kg Mo ha^{-1} and the lowest one (170 ppm) from control (Table 9). These results presented that the combined effect of zinc and molybdenum slightly increased the zinc content of tomato shoot.

4.3.2 Zinc uptake

Zinc uptake by shoot showed statistically significant variations for the effect of different levels of zinc under present trial (Table 10). Considering all doses, highest zinc was found (15.927 kg/ha) when they were fertilized with 9 Kg Zn/ha and the lowest zinc uptake (6.595 kg/ha) was found in the control treatment (Table 10). These results represented that higher doses of zinc increased zinc uptake in tomato shoot.

A statistically significant difference of zinc was recorded for different level of molybdenum by shoot. Among all the doses, highest zinc (12.035 kg/ha) was found when the plants were applied 1.0 kg Mo/ha and the lowest (9.967 kg/ha) from control (Table 10). These results represented that higher doses of molybdenum slightly increased the zinc uptake in tomato shoot.

The interaction effect of zinc and molybdenum on zinc uptake was significant. The highest value (16.59 kg/ha) was obtained when the plants were fertilized with 9 kg Zn ha^{-1}+1.5 kg Mo ha^{-1} and the lowest one (5.60 kg/ha) from control (Table 11). These results presented that the combined effect of zinc and molybdenum slightly increased the zinc uptake in tomato shoot.

4.3.3 Molybdenum content

Different level of molybdenum showed a significant effect on molybdenum content in shoot of tomato under the present experiment (Appendix IV). Considering all doses, highest molybdenum was found (17.26 ppm) when they were fertilized with 6 Kg Zn/ha and the lowest molybdenum content (12.28 ppm) was found in the control treatment (Table 8). These results represented that higher doses of zinc increased molybdenum content in tomato shoot.

The amount of molybdenum taken up by tomato plant with in a different doses of molybdenum resulted significantly higher value over the control (Appendix IV). Among all the doses, highest zinc (20.26 ppm) was found when the plants were applied 1.5 kg Mo/ha and the lowest (6.98 ppm) from control (Table 8). These results represented that higher doses of molybdenum slightly increased the molybdenum content of tomato shoot.

Combined effect of different doses of zinc and molybdenum on molybdenum concentration in shoot showed a statistically significant variation (appendix IV). The highest value (21.78 ppm) was obtained when the plants were fertilized with 9 kg Zn ha^{-1}+1.5 kg Mo ha^{-1} and the lowest one (5.81 ppm) from control (Table 9). These results presented that the combined effect of zinc and molybdenum slightly increased the molybdenum content of tomato shoot.

4.3.4 Molybdenum uptake

Molybdenum uptake by shoot showed statistically significant variations for the effect of different levels of zinc under present trial (Table 10). Considering all doses, highest Molybdenum was found (0.727 kg/ha) when they were fertilized with 9 Kg Zn/ha and the lowest Molybdenum uptake (0.425 kg/ha) was found in the control treatment (Table 10). These results represented that higher doses of zinc increased Molybdenum uptake of tomato shoot.

A statistically significant difference of Molybdenum was recorded for different level of molybdenum by shoot. Among all the doses, highest Molybdenum (0.831 kg/ha) was found when the plants were applied 1.5 kg Mo/ha and the lowest (0.261 kg/ha) from control (Table 10). These results represented that higher doses of molybdenum slightly increased the Molybdenum uptake of tomato shoot.

The interaction effect of zinc and molybdenum on Molybdenum uptake was significant. The highest value (1.007 kg/ha) was obtained when the plants were fertilized with 6 kg Zn ha^{-1}+1.5 kg Mo ha^{-1} and the lowest one (0.181 kg/ha) from control (Table 11). These results presented that the combined effect of zinc and molybdenum slightly increased the Molybdenum uptake of tomato shoot.

Table 8: Effect of zinc and molybdenum on vitamin-A, vitamin-C, Zinc and molybdenum content in tomato

Treatment	Vitamin-A (µg/100g) /plant	Vitamin-C (mg/100g) /plant	Zinc content (ppm) /plant	Molybdenum content (ppm) /plant
Zinc				
Zn_0	5028.0c	12.26c	190.3c	12.28b
Zn_3	5471.0b	14.56b	279.0b	16.72a
Zn_6	6414.0a	17.52a	286.8b	17.26a
Zn_9	6444.0a	17.29a	361.5a	16.51a
$SE_{(0.05)}$	77.61	0.2503	6.217	0.3276
CV(%)	4.70	5.63	7.71	7.23
Molybdenum				
Mo_0	5599.0c	14.04c	266.5b	6.983d
$Mo_{0.5}$	5758.0bc	15.22b	276.3ab	16.70c
$Mo_{1.0}$	5958.0ab	16.13a	290.3a	18.83b
$Mo_{1.5}$	6047.0a	16.24a	284.6ab	20.26a
$SE_{(0.05)}$	89.62	0.2891	7.179	0.3783
CV(%)	4.70	5.63	7.71	7.23

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

Zn_0 : 0 kg Zn/ha
Zn_3 : 3 kg Zn/ha
Zn_6 : 6 kg Zn/ha
Zn_9 : 9 kg Zn/ha

Mo_0 : 0 kg Mo/ha
$Mo_{0.5}$: 0.5 kg Mo/ha
$Mo_{1.0}$: 1.0 kg Mo/ha
$Mo_{1.5}$: 1.5 kg Mo/ha

Table 9: Interaction effect of zinc and molybdenum on vitamin-A, vitamin-C, Zinc and molybdenum content of tomato

Treatment combination	Vitamin-A content/plant (µg/100g)	Vitamin-C content/plant (mg/100g)	Zinc content (ppm) /plant	Molybdenum content (ppm) /plant
Zn_0Mo_0	48.62.0e	11.50f	170.0d	5.81i
$Zn_0Mo_{0.5}$	4978.0e	11.65f	180.0cd	11.81g
$Zn_0Mo_{1.0}$	5100.0de	12.64ef	200.0cd	14.77f
$Zn_0Mo_{1.5}$	5172.0de	13.24de	211.0c	16.75e
Zn_3Mo_0	5144.0de	13.65c-e	266.0b	6.67hi
$Zn_3Mo_{0.5}$	5290.0de	14.39b-d	279.0b	18.31c-e
$Zn_3Mo_{1.0}$	5578.0cd	14.88bc	285.0b	20.14a-c
$Zn_3Mo_{1.5}$	5872.0bc	15.33b	286.0b	21.77a
Zn_6Mo_0	6166.0ab	15.33b	290.0b	7.520hi
$Zn_6Mo_{0.5}$	6344.0ab	17.60a	294.0b	18.89b-d
$Zn_6Mo_{1.0}$	6568.0a	18.61a	300.0b	20.75ab
$Zn_6Mo_{1.5}$	6579.0a	18.55a	263.3b	21.87a
Zn_9Mo_0	6200.0ab	15.68b	340.0a	7.93h
$Zn_9Mo_{0.5}$	6421.0a	17.23a	352.0a	17.81de
$Zn_9Mo_{1.0}$	6578.0a	18.45a	376.0a	19.67b-d
$Zn_9Mo_{1.5}$	6566.0a	17.79a	378.0a	20.64ab
$SE_{(0.05)}$	155.2	0.5007	12.43	0.6552
CV(%)	4.70	5.63	7.71	7.23

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

Zn_0 : 0 kg Zn/ha Mo_0 : 0 kg Mo/ha
Zn_3 : 3 kg Zn/ha $Mo_{0.5}$: 0.5 kg Mo/ha
Zn_6 : 6 kg Zn/ha $Mo_{1.0}$: 1.0 kg Mo/ha
Zn_9 : 9 kg Zn/ha $Mo_{1.5}$: 1.5 kg Mo/ha

Table 10. Effect of zinc and molybdenum on vitamin-A, vitamin-C, Zinc and molybdenum uptake of tomato

Treatment	Vitamin-A (g/ha)/plant	Vitamin-C (g/ha)/plant	Zinc uptake(kg/ha) /plant	Molybdenum uptake(kg/ha) /plant
Zinc				
Zn_0	1742.70d	4249.32cd	6.5957d	0.425d
Zn_3	2109.60c	5614.34c	10.758c	0.645c
Zn_6	2838.84ab	7754.35a	12.693b	0.764ab
Zn_9	2839.23a	7617.97ab	15.927a	0.727a
$SE_{(0.05)}$	265.3	177.46	2.46	0.998
CV(%)	8.97	5.48	3.94	2.76
Molybdenum				
Mo_0	2094.02c	5250.96c	9.967c	0.261c
$Mo_{0.5}$	2281.32b	6030.16b	10.947b	0.662b
$Mo_{1.0}$	2470.19ab	6687.50a	12.035a	0.781ab
$Mo_{1.5}$	2479.27a	6658.40ab	11.668ab	0.831a
$SE_{(0.05)}$	294.98	187.67	1.019	1.008
CV(%)	8.97	5.48	3.94	2.76

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

Zn_0 : 0 kg Zn/ha
Zn_3 : 3 kg Zn/ha
Zn_6 : 6 kg Zn/ha
Zn_9 : 9 kg Zn/ha

Mo_0 : 0 kg Mo/ha
$Mo_{0.5}$: 0.5 kg Mo/ha
$Mo_{1.0}$: 1.0 kg Mo/ha
$Mo_{1.5}$: 1.5 kg Mo/ha

Table 11. Interaction effect of zinc and molybdenum on vitamin-A, vitamin-C, Zinc and molybdenum uptake of tomato

Treatment combination	Vitamin-A (g/ha)/plant	Vitamin-C (g/ha)/plant	Zinc uptake(kg/ha) /plant	Molybdenum uptake(kg/ha) /plant
Zn_0Mo_0	1512.57i	3577.65j	5.60k	0.181j
$Zn_0Mo_{0.5}$	1757.73hi	4113.62ij	7.06jk	0.395g
$Zn_0Mo_{1.0}$	1825.80g-i	4525.12hi	7.56jk	0.529ef
$Zn_0Mo_{1.5}$	1884.68g-i	4824.65hi	9.70g-i	0.577e
Zn_3Mo_0	1941.86gh	5152.87gh	10.53gh	0.252e
$Zn_3Mo_{0.5}$	2012.32fg	5473.96e-h	10.84gh	0.696cd
$Zn_3Mo_{1.0}$	2166.50fg	5779.39e-g	11.10fg	0.782a-c
$Zn_3Mo_{1.5}$	1735.18hi	4530.02hi	8.45i	0.861ab
Zn_6Mo_0	2495.10ef	6205.58ef	11.75e-g	0.304gh
$Zn_6Mo_{0.5}$	2692.39e	7469.44a-d	12.48e	0.802a-c
$Zn_6Mo_{1.0}$	3090.90a	8757.86a	14.12cd	0.976ab
$Zn_6Mo_{1.5}$	3030.95ab	8545.98ab	12.13ef	1.007a
Zn_9Mo_0	2496.12ef	6312.76de	13.69d	0.319gh
$Zn_9Mo_{0.5}$	2740.48cd	7353.76c-e	15.02a-c	0.760c
$Zn_9Mo_{1.0}$	2902.07abc	8141.98a-c	16.59a	0.868ab
$Zn_9Mo_{1.5}$	2755.75cd	7466.46a-d	15.86ab	0.866ab
$SE_{(0.05)}$	399.56	248.4	0.97	0.05
CV(%)	8.97	5.48	3.94	2.76

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

Zn_0 : 0 kg Zn/ha Mo_0 : 0 kg Mo/ha
Zn_3 : 3 kg Zn/ha $Mo_{0.5}$: 0.5 kg Mo/ha
Zn_6 : 6 kg Zn/ha $Mo_{1.0}$: 1.0 kg Mo/ha
Zn_9 : 9 kg Zn/ha $Mo_{1.5}$: 1.5 kg Mo/ha

4.4 Nutrient status of soil after harvest of tomato as affected by zinc and molybdenum

4.4.1 Soil pH

Single mean effect of different levels of zinc and molybdenum were not found significant on the p^H in post harvest soil of tomato. Zinc level of 6 kg ha^{-1} gave the highest p^H in post harvest soil (6.18) which was followed by Zn_9 treatment (5.81) and Zn_3 treatment (5.59) while Zn_0 treatment (0 kg zinc) gave the lowest p^H (5.56). On the other hand, the highest p^H (5.96) was recorded with the treatments of $Mo_{1.5}$ (1.5 kg molybdenum) and the lowest molybdenum concentration (5.77) with Mo_0 treatment where no molybdenum was applied (Table 12).

Combined application of zinc and molybdenum showed insignificant effect respecting soil pH after harvest of tomato is presented in (Table13). Soil pH was varied significantly at 5.49 to 6.31. The highest pH of the soil (6.31) was recorded in $Zn_3Mo_{1.5}$ treatment combination and the lowest pH value (5.49) was recorded in (Zn_0Mo_0) treatment combination where no zinc and molybdenum were applied which was statistically similar with treatment combinations of $Zn_3Mo_{0.5}$, $Zn_0Mo_{1.0}$ and $Zn_0Mo_{1.5}$.

4.4.2 Organic matter content of soil

Single mean effect of different levels of zinc and molybdenum were found significant on the organic matter of post harvest soil of tomato. Zinc level of 6 kg ha^{-1} gave the highest organic matter in post harvest soil (1.46%) followed by Zn_9 treatment and Zn_3 treatment (1.26%) while Zn_0 treatment (0 kg zinc) gave the lowest organic matter (0.93%). On the other hand, the highest organic matter (1.21%) (Table12) was recorded with the treatments of $Mo_{1.5}$ (1.5 kg molybdenum) and the lowest organic matter (1.04%) with Mo_0 treatment where no molybdenum was applied (Table 12).

A significant variation was observed in organic matter content in soil after harvest of tomato. Among the different treatment combinations the highest organic matter content (1.60%) was obtained where 6 kg Zn and 1.0 kg Mo were applied which was statistically identical with $Zn_6Mo_{1.5}$ treatment combination (1.57% OM). On the other hand, the lowest OM content (0.86%) was observed in the $Zn_0Mo_{1.5}$ treatment combination (Table 13) where no zinc and molybdenum were applied.

4.4.3 Total nitrogen content of soil

Single mean effect of different levels of zinc and molybdenum were found significant on the nitrogen content of post harvest soil of tomato. Zinc level of 6 kg ha^{-1} gave the highest nitrogen content in post harvest soil (0.10%) while Zn_0 (0 kg zinc), Zn_9 (9 kg zinc) and Zn_3 (3 kg zinc) treatments gave the lowest nitrogen content (0.09%). On the other hand, the highest nitrogen content (0.10%) was recorded with the treatment of $Mo_{1.0}$ (1.0 kg molybdenum) and the lowest organic matter (0.07%) with Mo_0 treatment where no molybdenum was applied (Table 12).

Total nitrogen content of soil after harvest of tomato was influenced by different doses of zinc and molybdenum showed a statistically significant variation (Table12). The highest N content (0.11%) of soil was observed in $Zn_6Mo_{1.0}$ treatment combination (6 kg Zn & 1.0 kg Mo) and it was statistically similar (0.10%) with the $Zn_9Mo_{1.0}$ treatment combination. The next highest N concentration was obtained from treatment combinations of $Zn_3Mo_{0.5}$, $Zn_3Mo_{1.5}$ and $Zn_0Mo_{1.5}$. In contrast, the lowest N content (0.08%) was obtained in the Zn_0Mo_0 treatment combination where no zinc and molybdenum were applied. This may be due to the fact that highest yield was obtained by uptake more amount of nitrogen from soil by plant.

4.4.4 Phosphorous content of soil

Single mean effect of different levels of zinc and molybdenum were found significant on the available phosphorus content of post harvest soil of tomato. Six kg zinc ha^{-1} gave the highest available phosphorus content (21.40 mg/kg) in post harvest soil followed by the treatments Zn_9 (18.99 mg/kg) and Zn_3 (18.27 mg/kg) while Zn_0 treatment (0 kg zinc) gave the lowest available phosphorus content (16.39 mg/kg) .On the other hand, the highest available phosphorus content (20.34 mg/kg) was recorded with the treatments of $Mo_{1.0}$ (1.0kg molybdenum) and the lowest available phosphorus content (16.77 mg/kg) with Mo_0 treatment where no molybdenum was applied (Table 12).

Different treatment combinations of zinc and molybdenum on the available phosphorous content of soil after harvest of tomato showed significant variation is presented in (Table 13). It was revealed from the study that the performances of the most of the treatment differ significantly from each other. Among the different treatment combinations, $Zn_6Mo_{1.0}$ treatment combination showed the highest P content (24.03 mg/kg) in soil after the harvest of tomato. On the other hand, the lowest P content (16.25 mg/kg) was observed in Zn_0Mo_0 treatment combination receiving where no zinc and molybdenum were applied.

4.4.5 Potassium content of soil

Single mean effect of different levels of zinc and molybdenum were found significant on the available potassium content of post harvest soil of tomato. Zinc level of 6 kg ha^{-1} gave the highest available potassium content in post harvest soil (0.22 mg/kg) followed by the treatment of Zn_9 (0.20 mg/kg) and Zn_3 (0.18 mg/kg) while Zn_0 treatment (0 kg zinc) gave the lowest available potassium content (0.14 mg/kg). On the other hand, the highest available potassium content (0.21 mg/kg) was recorded with the treatments of $Mo_{1.0}$ (1.0 kg molybdenum) and the lowest available potassium content (0.15 mg/kg) with Mo_0 treatment where no molybdenum was applied (Table 12).

The combined effect of zinc and molybdenum treatment combinations showed significant differences in respect of K content of soil after harvest of tomato (Table 13). However, the lowest K content of crop-harvested soil (0.12 mg/kg) was recorded in Zn_0Mo_0 treatment combination where no zinc and molybdenum were applied. The highest K content (0.25 mg/kg) was recorded with $zn_6Mo_{1.0}$ treatment combination followed by (0.24 mg/kg) in $Zn_6Mo_{1.5}$ treatment combination where 6kg zinc and 1.5 kg molybdenum per hectare were applied.

4.4.6 Sulphur content of soil

Single mean effect of different levels of zinc and molybdenum were found significant on the available sulphur content of post harvest soil of tomato. Six kg zinc ha^{-1} gave the highest available sulphur content (23.47 mg/kg) in post harvest soil followed by the treatments Zn_9 (19.97 mg/kg) and Zn_3 (19.73 mg/kg) while Zn_0 treatment (0 kg zinc) gave the lowest the available sulphur content (18.33 mg/kg) (Table 12).

On the other hand, the highest available sulphur content (22.78 mg/kg) was recorded with the treatments $Mo_{1.0}$ (1.0 kg molybdenum) and the lowest available sulphur content (17.63 mg/kg) with Mo_0 treatment where no molybdenum was applied (Table 12).

Statistically significant difference was obtained in the S content of soil after harvest of tomato. Application of 9 kg Zn and 1.0 kg Mo showed the highest S content (26.00 mg/kg) in soil. The next highest S content (24.28 mg/kg) was found in treatment combination ($Zn_9Mo_{1.5}$) receiving 9 kg Zn and 1.5 kg Mo. On the contrary, the lowest S content (15.49 mg/kg) was observed in the Zn_0Mo_0 treatment combination where no zinc and molybdenum were applied (Table 13).

Table 12. Effect of zinc and molybdenum on p^H, organic matter, total nitrogen, available P K and S in the soil after harvesting of tomato

Treatment	p^H	Organic matter %	Total (N) %	Available P (mg/kg)	Available K (mg/kg)	Available S (mg/kg)
Zinc						
Zn_0	5.56cd	0.93d	0.09b	16.39c	0.14cd	18.33d
Zn_3	5.59c	1.26c	0.08c	18.27ab	0.018c	19.73bc
Zn_6	6.18a	1.46a	0.10a	21.40a	0.22a	23.47a
Zn_9	5.81b	1.46a	0.07d	18.99b	0.20ab	19.97b
$SE_{(0.05)}$	0.76	0.67	0.008	0.124	1.21	1.514
CV(%)	3.53	7.87	5.16	6.89	6.69	7.29
Molybdenum						
Mo_0	5.77c	1.04cd	0.07cd	16.77c	0.15cd	17.63c
$Mo_{0.5}$	5.68cd	1.08c	0.08c	19.12d	0.18c	20.25cd
$Mo_{1.0}$	5.90ab	1.18a	0.10a	20.34a	0.21a	22.78a
$Mo_{1.5}$	5.96a	1.21ab	0.90ab	20.30ab	0.20ab	22.53ab
$SE_{(0.05)}$	0.92	0.87	0.49	0.124	1.21	1.514
CV(%)	3.53	7.87	5.16	6.89	6.69	7.29

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

Zn_0: 0 kg Zn/ha Mo_0 : 0 kg Mo/ha

Zn_3: 3 kg Zn/ha $Mo_{0.5}$: 0.5 kg Mo/ha

Zn_6: 6 kg Zn/ha $Mo_{1.0}$: 1.0 kg Mo/ha

Zn_9: 9 kg Zn/ha $Mo_{1.5}$: 1.5 kg Mo/ha

Table13. Interaction effect of zinc and molybdenum on p^H, organic matter, total nitrogen, available P K and S in the soil after harvesting of tomato

Treatment combination	p^H	OM %	Total N %	Available P (mg/kg)	Available K (mg/kg)	Available S(mg/kg)
Zn_0Mo_0	5.49e	1.02f	0.08d	15.00i	0.12i	15.49h
$Zn_0Mo_{0.5}$	5.53e	0.94f	0.08cd	17.11g	0.14g	16.11h
$Zn_0Mo_{1.0}$	5.61de	0.88ef	0.10cd	17.20g	0.16f	21.43cd
$Zn_0Mo_{1.5}$	5.62de	0.86de	0.09c	16.25h	0.15e	20.29e
Zn_3Mo_0	5.82de	1.08c-e	0.09b	16.28h	0.15hi	17.00g
$Zn_3Mo_{0.5}$	5.90de	1.20b-d	0.07b	17.48e-g	0.19c-e	20.48e
$Zn_3Mo_{1.0}$	5.86cd	1.36bc	0.08b	18.91e	0.20a-c	21.44cd
$Zn_3Mo_{1.5}$	6.32bc	1.40b	0.08b	20.43cd	0.21a	20.03ef
Zn_6Mo_0	5.97ab	1.18b	0.08b	17.44ef	0.16hi	18.52f
$Zn_6Mo_{0.5}$	6.05ab	1.50a	0.08b	22.11b	0.21bcd	18.11fg
$Zn_6Mo_{1.0}$	6.24a	1.60a	0.11a	24.03a	0.25a	22.28c
$Zn_6Mo_{1.5}$	6.31a	1.57a	0.09b	22.11b	0.24ab	21.00d
Zn_9Mo_0	5.82ab	0.86b	0.07a	17.11e	0.17h	19.49f
$Zn_9Mo_{0.5}$	5.83a	1.08a	0.09b	19.43e	0.22de	24.11b
$Zn_9Mo_{1.0}$	5.69a	0.98a	0.10a	21.22c	0.19b-d	26.00a
$Zn_9Mo_{1.5}$	5.92a	0.98a	0.08a	18.22e	0.23ab	24.28b
$SE_{(0.05)}$	1.016	0.94	0.39	1.68	0.46	1.82
CV(%)	3.53	7.87	5.16	6.89	6.69	7.29

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

Zn_0 : 0 kg Zn/ha Mo_0 : 0 kg Mo/ha

Zn_3 : 3 kg Zn/ha $Mo_{0.5}$: 0.5 kg Mo/ha

Zn_6 : 6 kg Zn/ha $Mo_{1.0}$: 1.0 kg Mo/ha

Zn_9 : 9 kg Zn/ha $Mo_{1.5}$: 1.5 kg Mo/ha

Chapter V
Summary and Conclusions

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University (SAU) farm, Bangladesh during the period from November 2008 to March 2009 to find out the effect of zinc and molybdenum on the yield and quality of tomato. The seed of tomato variety BARI tomato-9 (Lalima) was collected from the BARI farm. The experiment considered of two factors as Factor A (Four levels of zinc): Zn_0: 0 kg Zn/ha; Zn_3: 3 kg Zn/ha; Zn_6: 6 kg Zn/ha and Zn_9: 9 kg Zn/ha, Factor B (Four levels of molybdenum): Mo_0: 0 kg Mo/ha; $Mo_{0.5}$: 0.5 kg Mo/ha; $Mo_{1.0}$: 1.0 kg Mo/ha and $Mo_{1.5}$: 1.5 kg Mo/ha. There were 16 (4 x 4) treatment combinations. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data were recorded on yield contributing characters and yield of tomato, zinc and molybdenum uptake by plant and their availability in soil.

The maximum plant height (63.63 cm) was recorded in Zn_6 treatment consisting of 6kg Zn/ha and the minimum plant height (55.33 cm) was recorded in Zn_0 treatment i.e. control condition. The highest number of leaf (25.27) was recorded from Zn_6 treatment consisting of 6kg Zn/ha and the lowest number of leaf (20.72) was recorded from Zn_0 treatment i.e. control condition. The maximum number of branch (7.85) was recorded from Zn_6 treatment consisting of 6kg Zn/ha and the minimum number of branch (6.55) was recorded from Zn_0 treatment i.e. control condition. The maximum number of flower cluster (23.08) per plant was recorded Zn_6 treatment and the minimum (16.42) was recorded under Zn_0 treatment. The maximum number of flower (114.1) per plant was recorded Zn_6 treatment and the minimum (92.25) was recorded under Zn_0 treatment. The maximum number of fruits (44.17) per plant was recorded from Zn_6 treatment and the minimum number of fruits (33.83) per plant was recorded from Zn_0 treatment. The highest single weight of fruits (35.17 gm) per plant was recorded from Zn_6 treatment and the lowest weight of single fruits (32.06 gm) per plant was recorded from Zn_0 treatment. The maximum yield (19.81 kg) per plot was recorded from Zn_6 treatment and the minimum yield (15.60 kg) per plot was recorded from Zn_0 treatment. The maximum yield (44.26 tonnes) per hectare was recorded from Zn_6 treatment and the minimum yield (34.66 tones) per hectare was recorded from Zn_0 treatment. The highest vitamin-A content (6444.0 μg/100g) in plant was recorded from Zn_9 treatment and the lowest vitamin-A (5028.0) μg/100g was recorded from Zn_0 treatment. The highest yield of vitamin-A (2839.23 g/ha) in plant was recorded from Zn_9 treatment and the lowest yield of vitamin-A (1742.70 g/ha) was recorded from Zn_0 treatment. The highest vitamin-C content (17.52 mg/100g) in plant was recorded from Zn_6 treatment and the lowest vitamin-C content (12.26 mg/100g) was recorded from Zn_0 treatment. The highest Yield of vitamin-C (7754.35 g/ha) in plant was recorded from Zn_6 treatment and the lowest vitamin-C (4249.32 g/ha) was recorded from Zn_0 treatment. The highest zinc content (361.5 ppm) in plant was recorded from Zn_9 treatment and the lowest zinc content (190.3 ppm) was recorded from Zn_0 treatment. The highest zinc uptake (15.927 kg/ha) in plant was recorded from Zn_9 treatment and the lowest zinc uptake (6.595 kg/ha) was recorded from Zn_0 treatment. The highest molybdenum content (17.26 ppm) in plant was recorded from Zn_6 treatment and the lowest molybdenum content (12.28 ppm) was recorded from Zn_0 treatment. The highest molybdenum uptake (0.727 kg/ha) in plant was recorded from Zn_9 treatment and the lowest molybdenum content (0.425 kg/ha) was recorded from Zn_0 treatment.

The greatest plant height (62.70 cm) was recorded from $Mo_{1.0}$ treatment consisting of 1.0 kg Mo/ha and the lowest plant height (57.55 cm) was recorded from Mo_0 treatment i.e. control condition. The maximum number of leaf (25.16) per plant was recorded from $Mo_{1.0}$ treatment consisting of 1.0 kg Mo/ha and the minimum number of leaf (19.94) was recorded from Mo_0 treatment i.e. control condition. The maximum number of branch (7.91) per plant was recorded from $Mo_{1.0}$ treatment consisting of 1.0 kg Mo/ha and the minimum number of branch (6.24) was recorded from Mo_0 treatment i.e. control condition. The maximum number of flower cluster (22.38) per plant was recorded from $Mo_{1.0}$ treatment consisting of 1.0 kg Mo/ha and the minimum number of flower cluster (17.70) was recorded from Mo_0 treatment i.e. control condition. The maximum number of flower (111.8) per plant was recorded from $Mo_{1.0}$ treatment consisting of 1.0 kg Mo/ha and the minimum number of flower (93.68) was recorded from Mo_0 treatment i.e. control condition. The maximum number of fruits (42.49) per plant was recorded from $Mo_{1.0}$ treatment and the minimum number of fruits (34.75) per plant was recorded from Mo_0 treatment. The maximum fruits weight (34.47 gm) per plant was recorded from $Mo_{1.0}$ treatment and the minimum fruits (30.83 gm) per plant was recorded from Mo_0 treatment. The maximum yield (18.66 kg) per plot was recorded from $Mo_{1.0}$ treatment and the minimum yield (16.83 kg) per plot was recorded from Mo_0 treatment. The maximum yield (41.46 t/ha) was recorded from $Mo_{1.0}$ treatment and the minimum yield (37.4 t/ha) was recorded from Mo_0 treatment. The highest vitamin-A content (6047.0 μg/100g) in plant was recorded from $Mo_{1.5}$ treatment and the lowest vitamin-A (5593.0 μg/100g) was recorded from Mo_0 treatment. The highest yield of vitamin-A (2479.27 g/ha) in plant was recorded from $Mo_{1.5}$ treatment and the lowest vitamin-A (2094.02 g/ha) was recorded from Mo_0 treatment. The highest vitamin-C content (16.24 mg/100g) in plant was recorded from $Mo_{1.5}$ treatment and the lowest vitamin-C content (14.04 mg/100g) was recorded from Mo_0 treatment. The highest yield of vitamin-C (6687.50 g/ha) in plant was recorded from $Mo_{1.0}$ treatment and the lowest vitamin-C (5250.96 g/ha) was recorded from Mo_0 treatment. The highest zinc content (290.3 ppm) in plant was recorded from $Mo_{1.0}$ treatment and the lowest zinc content (266.5 ppm) was recorded from Mo_0 treatment. The highest zinc uptake (12.035 kg/ha) in plant was recorded from $Mo_{1.0}$ treatment and the lowest zinc uptake (9.967 kg/ha) was recorded from Mo_0 treatment. The highest molybdenum content (20.26 ppm) in plant was recorded from $Mo_{1.0}$ treatment and the lowest molybdenum content (6.98 ppm) was recorded from Mo_0 treatment. The highest molybdenum uptake (0.831

kg/ha) in plant was recorded from $Mo_{1.5}$ treatment and the lowest molybdenum content (0.261 kg/ha) was recorded from Mo_0 treatment.

The maximum plant height (66.80) was recorded from treatment combination $Zn_6Mo_{1.5}$ as 6 kg Zn/ha+1.5 kg Mo/ha, while the minimum plant height (53.78 cm) was recorded from treatment combination Zn_0Mo_0. The maximum number of leaf (27.44) was recorded from treatment combination $Zn_6Mo_{1.0}$ as 6 kg Zn/ha+1.0 kg Mo/ha, while the minimum number of leaf (17.67) was recorded from treatment combination Zn_0Mo_0. The maximum number of branch (8.44) was recorded from treatment combination $Zn_6Mo_{1.0}$ as 6 kg Zn/ha+1.0 kg Mo/ha, while the minimum number of branch (5.10) was recorded from treatment combination Zn_0Mo_0. The maximum number of flower cluster (25.70) was recorded from treatment combination $Zn_6Mo_{1.0}$ as 6 kg Zn/ha+1.0 kg Mo/ha, while the number of flower cluster (14.20) was recorded from treatment combination Zn_0Mo_0.
The maximum number of flower (123.7) was recorded from treatment combination $Zn_6Mo_{1.0}$ as 6 kg Zn/ha+1.0kgMo/ha, while the minimum number of flower (82.00) was recorded from treatment combination Zn_0Mo_0. The maximum number of fruits (48.67) was recorded from treatment combination $Zn_6Mo_{1.0}$ as 6 kg Zn/ha+1.0 kg Mo/ha, while the minimum number of fruits (30.67) was recorded from treatment combination Zn_0Mo_0. The maximum fruits weight (37.75 gm) was recorded from treatment combination $Zn_6Mo_{1.0}$ as 6 kg Zn/ha+1.0kgMo/ha, while the minimum fruits weight (29.3 gm) was recorded from treatment combination Zn_0Mo_0. The maximum yield (21.18 kg/plot) was recorded from treatment combination $Zn_6Mo_{1.0}$ as 6 kg Zn/ha+1.0 kg Mo/ha, while the minimum yield (14.00 kg/plot) was recorded from treatment combination Zn_0Mo_0. The maximum yield (47.06 t/ha) was recorded from treatment combination $Zn_6Mo_{1.0}$ as 6 kg Zn/ha+1.0 kg Mo/ha, while the minimum yield (31.11t/ha) was recorded from treatment combination Zn_0Mo_0. The maximum vitamin-A content (6578.0 μg/100g) was recorded from treatment combination $Zn_9Mo_{1.0}$ as 9 kg Zn/ha+1.0 kg Mo/ha, while the minimum vitamin-A (4862.0 μg/100g) was recorded from treatment combination Zn_0Mo_0. The

maximum yield of vitamin-A (3090.90 g/ha) was recorded from treatment combination $Zn_6Mo_{1.0}$ as 6 kg Zn/ha+1.0 kg Mo/ha, while the minimum vitamin-A (1512.57 g/ha) was recorded from treatment combination Zn_0Mo_0. The maximum vitamin-C content (18.61 mg/100g) was recorded from treatment combination $Zn_6Mo_{1.0}$ as 6 kg Zn/ha+1.0 kg Mo/ha, while the minimum vitamin-C (11.50 mg/100g) was recorded from treatment combination Zn_0Mo_0. The maximum yield of vitamin-C (8757.86 g/ha) was recorded from treatment combination $Zn_6Mo_{1.0}$ as 6 kg Zn/ha+1.0 kg Mo/ha, while the minimum vitamin-C (3577.65 g/ha) was recorded from treatment combination Zn_0Mo_0. The maximum zinc content (378.0 ppm) was recorded from treatment combination $Zn_9Mo_{1.5}$ as 9 kg Zn/ha+1.5 kg Mo/ha, while the minimum zinc content (170.0 ppm) was recorded from treatment combination Zn_0Mo_0. The maximum zinc uptake (16.59 kg/ha) was recorded from treatment combination $Zn_9Mo_{1.0}$ as 9 kg Zn/ha+1.0 kg Mo/ha, while the minimum zinc uptake (5.60 kg/ha) was recorded from treatment combination Zn_0Mo_0. The maximum molybdenum content (20.87 ppm) was recorded from treatment combination $Zn_9Mo_{1.5}$ as 9 kg Zn/ha+1.5 kg Mo/ha, while the minimum molybdenum content (5.81 ppm) was recorded from treatment combination Zn_0Mo_0.The maximum molybdenum uptake (1.007 kg/ha) was recorded from treatment combination $Zn_6Mo_{1.5}$ as 6 kg Zn/ha+1.5 kg Mo/ha, while the minimum molybdenum uptake (0.181 kg/ha) was recorded from treatment combination Zn_0Mo_0. In conclusion, the best combination of zinc and molybdenum for the maximum yield and quality was recorded in $Zn_6Mo_{1.0}$.

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 region specific recommendation;
2. Another fertilizer or combined fertilizer may also included in the program for future study.

Chapter VI
References

REFERENCES

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

Ahmed, S. 1988. Crops response to applied molybdenum in Brahmaputra flood plain soil of Bangladesh. *Bagladesh J. Soil Sci.* **19**:36-41.

Annanurova, M. A., Rozyeva, M. T., Tailakov and Slovinskaya, L. P. 1992. Effect of fertilizers on some physiological process and fruit quality in tomatoes. *Izvestiya Akademii Nauk Turkmenistan* **3**: 49-53. [cited from Hort. abst., **64**(10): 7976, 1994].

Awasthi, C. P., Jaisswal, R.C., Singh, S. and Singh, I. S. 1992. Propagation of Horticultural Plants. Tata McGraw Hill Company Ltd., New Delhi. **pp.** 278-279.

Bajaj, K. L., Mahajan, Kaur, R. P. and Cheema, D. S. 1990. Chemical evaluation of some tomato varieties. *J. Res. Punjab Agric. Univ.*, **27**: 226-230.

Balasubramaniam, S. P., Abha and T. Sharma, N. K. 1998. Effect of zinc and boron application on yield, concentration and their uptake by tomato (*Lycopersicon esculentum* Mill). *Haryana Journal of Horticultural Sciences*. Horticultural Society of Haryana Hisar, India.: **30**(3/4): 251-253.

Bangladesh Bureau of Statistics (BBS). 2009. *Yearbook of Agricultural Statistics of Bangladesh,* Statistics Division, Ministry of Planning, Govt. of the Peoples Republic of Bangladesh, *p. 149.*

Bennet 1989. Requirement of supplementary fertilization on plants. *Trop. Sci.,* **32**(2): 95-97.

Bertic P., Jackson, E., Hayes, S. and Herber, V. *1991.* Molybdenum fertilization on the yield of tomato. *J. Amer. Soc. Hort. Sci.,* **99**: (3):9-12.

Black, C. A. 1965. *Methods of soil analysis.* Part-II. *Amer. Soc. Agron. Inc.* Medison, Washington, USA, pp. 999-1009, 1487-1492.

Bose,T. K. and Som, M. G. 1990. Vegetables crops in India. Naya Prakash, Calcutta, India. pp.224-225.

Bremner, J. M. and Mulvaney, C. S. 1982. Total Nitrogen in method of soil analysis Miller, R.H. and Xeeemy, D.R..1982. *Amer .Soc. Agron.Inc.* Madi.Wis USA.pp.593-622.

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

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

Das and Patro. 1985. Effects of different micronutrients on the growth, yield, disease (bacterial wilt, viruses) incidence and fruit quality of tomato (cv. Marglobe). *India. J. Hort.*, **15**: 50-55.

Davis, J. N. and Hobson, G. E. 1981. The constituents of tomato fruit - the influence of environment, nutrition and genotype. *Hort. Sci.,* **21**(8):415-421.

Day, P. R. 1965. Particle fractionation and particle size analysis. In methods of soil analysis, Part-1, C. A. Black (ed), *American society of Agronomy, Inc.*,Madison, Wisconsir, USA. Pp.548-577.

Dobromilska, R., Rekowska, E. and Kujath, K. 2004. Nutritional value and mineral composition of less known vegetables. *J. Elementology,* **9**(3):269-275.

Dod, V. N. and Kale, P. B. 1997. Performance of some tomato varieties under vidarbha conditions. *PKV Res. J.,* **21**(2):201-203.

Dube, B. K. Pratima-sinha, Chatterjee, C. 2003. Effects of zinc on the yield and quality of tomato. *Indian-Journal-of-Horticulture*. New Delhi, India. **60**(1): 59-63.

Dutta, R.K., Islam, M. S., Mia, Saset, M. A., Majid, M. A. and Lahiri, B. P. 1995. Comperative assessment of tomato varieties/advanced lines in relation to growth, yield and quality. *Bangladesh J. Nuclear Agric.* **11**:27-35.

El-Gharably, A. M., Tolba, K. H. and Rizk, E. M. 2004. Enrichment of some fruit and vegetable drinks with vitamin C from sweet pepper. *Anuals of Agril. Sci.,* Cairo, **49**(1):125-137.

Food and Agricultural Organization (FAO). 2002. Production Yearbook, 1996. Basic Data Unit, Statistics Division, FAO, Rome, Italy, **55**:139-141.

Fox, R. L., Olsen, R. A. and Rhoades, H. F. 1964. Evaluating the sul[hur status of soils by plant and soil tests. *Soil Sci. Soc. Amer. Proc.* **28**:243-246.

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.

Frazeria N. K., Jiang, V. and Hameleers, A. 1981. Mineral Nutrition of Higher Plants. Naya Prokash.Bidhansarani, Kolkata 700000, India. P. 80.

Freeh 1989. Mineral Nutrition. Tata Mcgraw Hill Company Ltd., New Delhi. pp. 158160.

Gomez., K. A. and Gomez, A. A. 1984. *Statistical Procedures for Agricultural* Research. 2nd Edn. John Willy and Sons, New York, pp. 18-192.

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

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

Hanson, P. M., Yu Yang-Ray, Wu, J. Chen-Jen Tzu, D. Ledesma, S. C. S. Tsou and Lee, T. C. 2004. Variation of antioxidant activity and antioxidants in toniato. *J. Amer. Soc.Hort. Sci.,* **129**(5):704-711.

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 soil. **306**(1/2): 13-22.

Hunt, J. 1980. Determination of total sulphur in small amount of plant material Analyst. **105**:83-85.

Islam, N. 1992. Resistance in Solanum species to Melodogyne incognita and pathogenicity and control of the nematode. A thesis submitted to the faculty of Agriculture, Bangladesh Agricultural University, Mymensingh. P. 40.

Islam, M. A., Farooque, A. M., Siddiqua, A. and Siddique 1997. *Effect of planting patterns and different nitrogen levels on yield and quality of tomato. Bangladesh J. Agril. Sci., **24**(1):9-15.*

Jackson, M. L. 1958. Soil Chemical Analysis. Prentice Hall of India Private Ltd. New Delhi, India.pp. 41-196.

Jain 1973. Effect of molybdenum on the yield of tomato *(Lycopersicon esculentum Mill.).Acta Hort.,* **257**:358-365.

Kalloo 1985. Tomato, Allied publishers Private Limited, New Delhi, India. **Pp**.204-211.

Katyal, I. C. and Randhawa, N. S. 1983 Micronutrients. FAO Fertilizer and plant nutrient bulletin. **pp** 3-76.

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

Keren, A. A., and Albright, M. 1985. Vegetative Characters of tomatoes as influenced by some micro nutrients. *J Amer. Soc. Hort. Sci.,* **107**(1):10-13.

Magalhaes, J. R. Dc; C. E.W. L, Solwa Dc. And Monnerat, P. H. 1980. Levels and Methods of boron application in tomatoes. Perquisa Agropecuria Brasilesia, **10**(2):153-157[cited from Hort. Abstr., **50**(40):2031,1981]

Merino, R. M. and Graham, R. D. 1999. Effect of different rates of NPK fertilizers on tomato. *J. Agril. Food Chem.* (USA).**41**(2):14-16.

Miller, S. E. and Donhue, B. N. 1997. Impact of molybdenum on nutrient concentration of tomato. *J. Agril. Food Chem.* (USA).**83**(1):9-12.

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.*

Mudholkar and Ahlawat 1979. Effect of phosphorus and molybdenum on plant productivity and grain yield. *Acta. Hort., **280**:* 250-255.

Naphade and Wankhade. 1987. Chemical fertilization on growth and growth attributes of tomato. *Acta Hort., **275**:* 180-185.

Navez, B., Jost, M., Buret, M. and Causse, M. 2004. Nutritional assets of tomato: impact of varieties and post harvest itinery.Infos-Ctifl, **204**:27-33.

Noion, S. and Islam, M. S. 1982. Response of tomato to different fertilizer elements and organic matter. *Bangladesh Hort.*, **19(1&2)**: 17-25.

Obata, H., 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.

Olsen, R.V. 1982. Iron *Inc. A.* Black *et al.* ed. *Methods of Soil Analysis, Part-2. Agron. J. Amerc. Soc. Agron.* Madison, Wis., *9:966-967.*

Patnaik, M. C., G. B. Raj, and Reddy, I. P. 2001. Response of tomato (*Lycopersicon esculentum* Mill.) to zinc and iron. Vegetable-Science.; **28**(1): 78-79.

Petersen, Leif 2002. Analytical Methods Soil, Water, Plant Material, Fertilizer. Soil Resources Management And Analytical Services. SRDI Danida Kampsax, Dhaka, **pp**. 61-69.

Petersen, Leif 2001. Analytical Methods Soil, Water, Plant Material, Fertilizer. Soil Resources Management And Analytical Services. SRDI Danida Kampsax, Dhaka, **pp**. 21-25.

Piper, C. S.1950. Soil and plant analysis. Adelaide Univ. press. Australia.

Ranganna, S. 1994. Manual of analysis of fruit and vegetable products. Tata McGrew-Hill Publishing Co. Ltd., New Delhi. **P**. 112.

Rahman, M. A., Saha, J. H. U. K., Chowdhury, A. R. and Chowdhury, M. M. U. 1996. Growth and yield of tomato as influenced by fertilizers and manures. Ann. Bangladesh Agric. Pub., *6: 71-74.*

Saimbhi, M. S., Cheema, D. S., Shing, S. and Nandpuri, K. S. 1987. Physico-chemical properties of some tomato hybrids. *Trop. Sci.*, **35**(1): 9-12.

Sarkar and Banik. 1991. Effect of molybdenum with N, P fertilizers on plant productivity and yield, fruit weight, no. of flowers of tomato plant. India. J. Hort., **12**: 49-53.

Shanna, S. C., and Chahal, T. K. 1983. Effect of molybdenum on the yield of tomato *(Lycopersicon esculentum Mill.). Acta Hort.,* **257**:274-290.

Sidhu. A. S. and Singh, S. 1989. Genetic variability and correlation for yield and quality characters in tomato *(Lycopersicon esculentum Mill.). Indian J. Agril. Sci.,* ***58****(12):810-812.*

Singh, A. K., Kashyap, M. M. A., Gupta, K. and Bhumbla, V. K. *1992.* Vitamin C during control atmosphere storage of tomatoes. *J. Res. Punjab Agril. (Ari.,* ***30****(3&4):199-203.*

Singh, A. K. and Sharma, J. P. 1993. Studies on the effect of variety and level of nitrogen on plant growth and development and yield of tomato hybrids (*lycopersicon esculentum* Mill.) *Annals of Agricultural Research.* **20**(4):502-503.

Solaiman, K. Prodan, M. and Chowdhury, A. R. *1991.* Effect of molybdenum and *Rhizobium* inoculants on two varieties of lentil, Utfala and *Mymensingh local. Hort.J.,* **15**(5):75-78.

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

Tadano, T. 1985. Nutritional factors limiting crop growth in problem soil and crop tolerance to them In;Proc. International seminar Environmental factors in Agricultural production, Thailand. Pp.314-345.

Tisdale, M. K., Bufler, G. and Blemar, P. R. 1997. Interaction of nutrient management with disease control in sweet Spanish onions. In T. A. Tindall and D. Westerman (ed) Proc. Western Nutrient manage. Conf. pp.119-126.

United States National Academy of Sciences, Food and Nutrition Board. 1990. Recommended Dietary Allowances, 10^{th} edition, National Academy Press, Washington D.C.

Walkley, A. C. and Black, T. A. 1935. Estimation of soil organic carbon by chromatic acid titration method. *Soil Sci.* **47**:29-38

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

Yadav, P.V. S., Abha-Tikkoo and Sharma, N. K. 2001. Effect of zinc and boron application on yield, concentration and their uptake by tomato (*Lycopersicon esculentum Mill*). *Haryana Journal of Horticultural Sciences*,; **30**(3/4): 251-253.

Yilmaz, A., Ekiz., H., Torun, B. Gultekin, I. Karanlyk, S. Bagey, and Cakmak, I. 1997. Different zinc application methods on grain yield and zinc concentrations in wheat grown on zinc deficient calcareous soils in central Anatolia. *J. Plant Nutr*. **20**:461-471.

Chapter VII

Appendix

Appendix I. Monthly record of air temperature(c), relative humidity(%), rainfall(mm) and sunshine hours during the period of experiment (November 2008 to February 2009).

Months	Air temperature (c)			Relative humidity (%)	Rainfall (mm)	Sunshine (hrs)
	Temperature (Maximum)	Temperature (minimum)	Average			
November	29.52	18.99	24.25	56.20	2.3	6.50
December	25.91	13.55	19.73	45.79	2.61	6.79
January	24.38	13.32	18.85	50.29	2.54	7.12
February	24.63	13.79	19.21	48.54	3.06	7.39
March	25.1	15.49	20.29	50.10	4.01	8.10

Source: Weather Yard, Bangladesh Metrological Department, Dhaka

Appendix II. Analysis of variance of the data on plant height, number of leaf, number of branch and number of flower cluster of tomato as influenced by zinc and molybdenum

Source of variation	Degrees of freedom	Mean square			
		Plant height	Number of leaf	Number of branch	Number of flower cluster
Replication	2	9.551	3.010	0.486	13.087
Zinc (A)	3	194.829**	43.152**	4.203**	106.546**
Molybdenum (B)	3	69.241**	69.814**	7.668**	56.288**
Interaction (A ×B)	9	13.844*	6.947*	2.341*	5.633
Error	30	5.725	2.950	0.106	2.221

Appendix III. Analysis of variance of the data on number of flower, number fruit, weight of single fruit, and yield of tomato as influenced by zinc and molybdenum

Source of variation	Degrees of freedom	Mean square			
		Number flower	Number of fruit	Weight of single fruit	Yield (t/ha)
Replication	2	12.56	3.562	8.062	8.65
Zinc (A)	3	1292.091**	247.04**	27.090*	267.029**
Molybdenum(B)	3	856.262**	157.925**	31.025**	60.864**
Interaction (A ×B)	9	133.584*	15.687*	12.941*	23.60*
Error	30	29.429	6.362	6.463	7.39

Appendix IV. Analysis of variance of the data on vitamin-A, vitamin-C, zinc uptake and molybdenum uptake of tomato as influenced by zinc and molybdenum

Source of variation	Degrees of freedom	Mean square			
		vitamin-A	Vitamin-C	Zinc uptake	Molybdenum uptake
Replication	2	624.388	0.514	37.333	0.557
Zinc (A)	3	5958394.414**	74.577**	58974.188**	63.379**
Molybdenum (B)	3	498761.212**	12.502**	1283.688**	430.164**
Interaction (A ×B)	9	75288.38*	2.223*	911.021*	4.995*
Error	30	27331.190	0.752	463.867	1.288

Appendix V. Figure on growth and yield contributing characters of BARI tomato-9 (lalima)

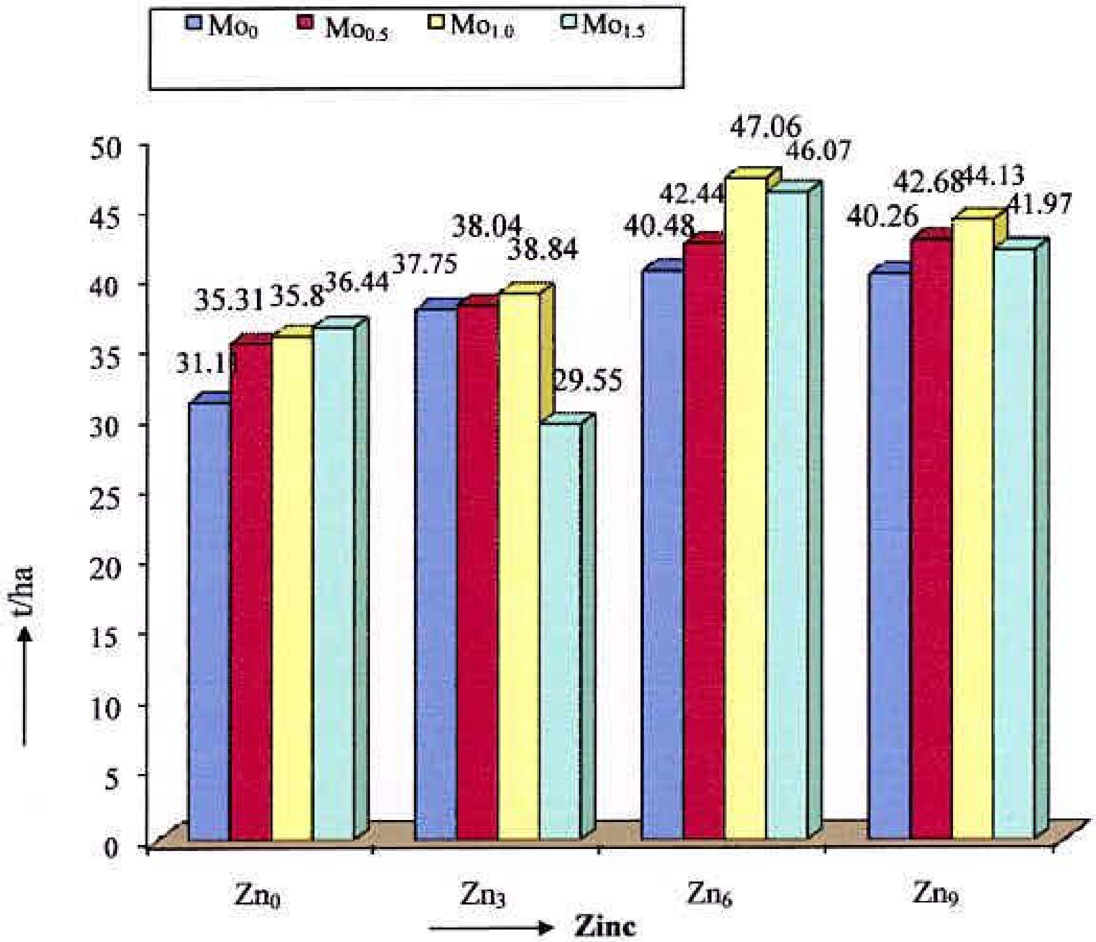


Figure 1: Interaction effect of zinc and molybdenum on yield (t/ha) of tomato

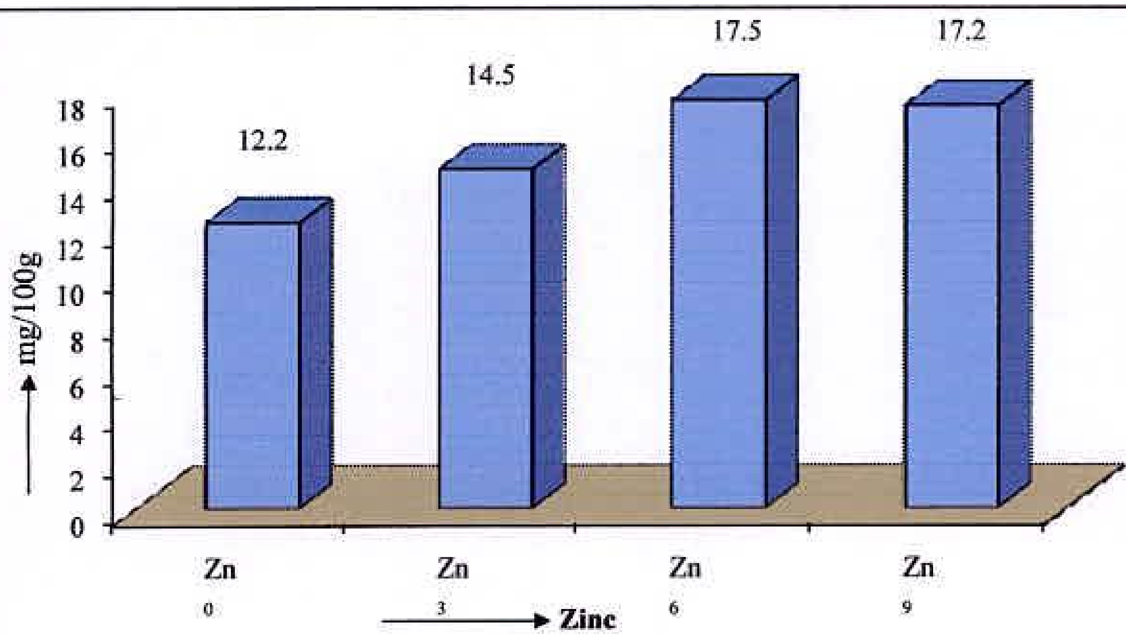


Figure 2: Effect of zinc on vitamin-C of tomato

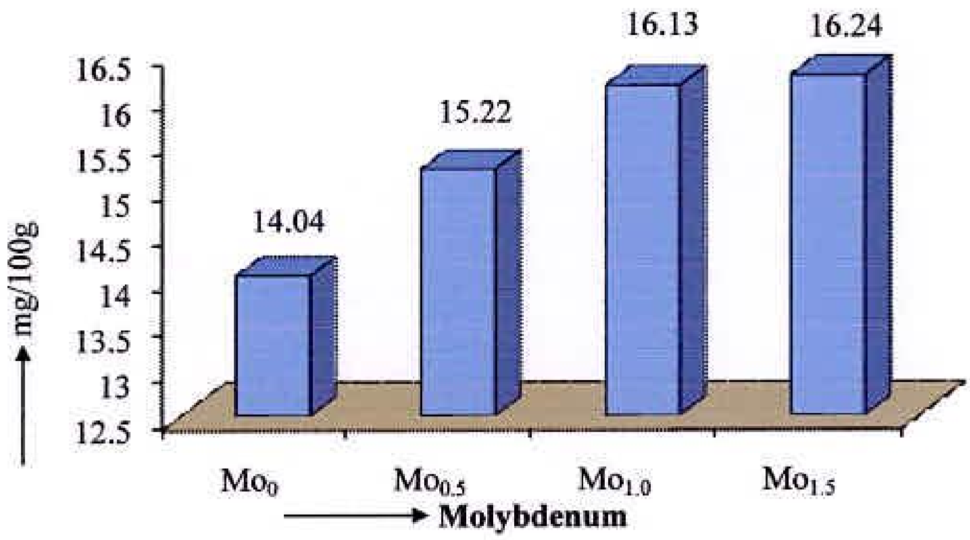


Figure 3: Effect of molybdenum on vitamin-C of

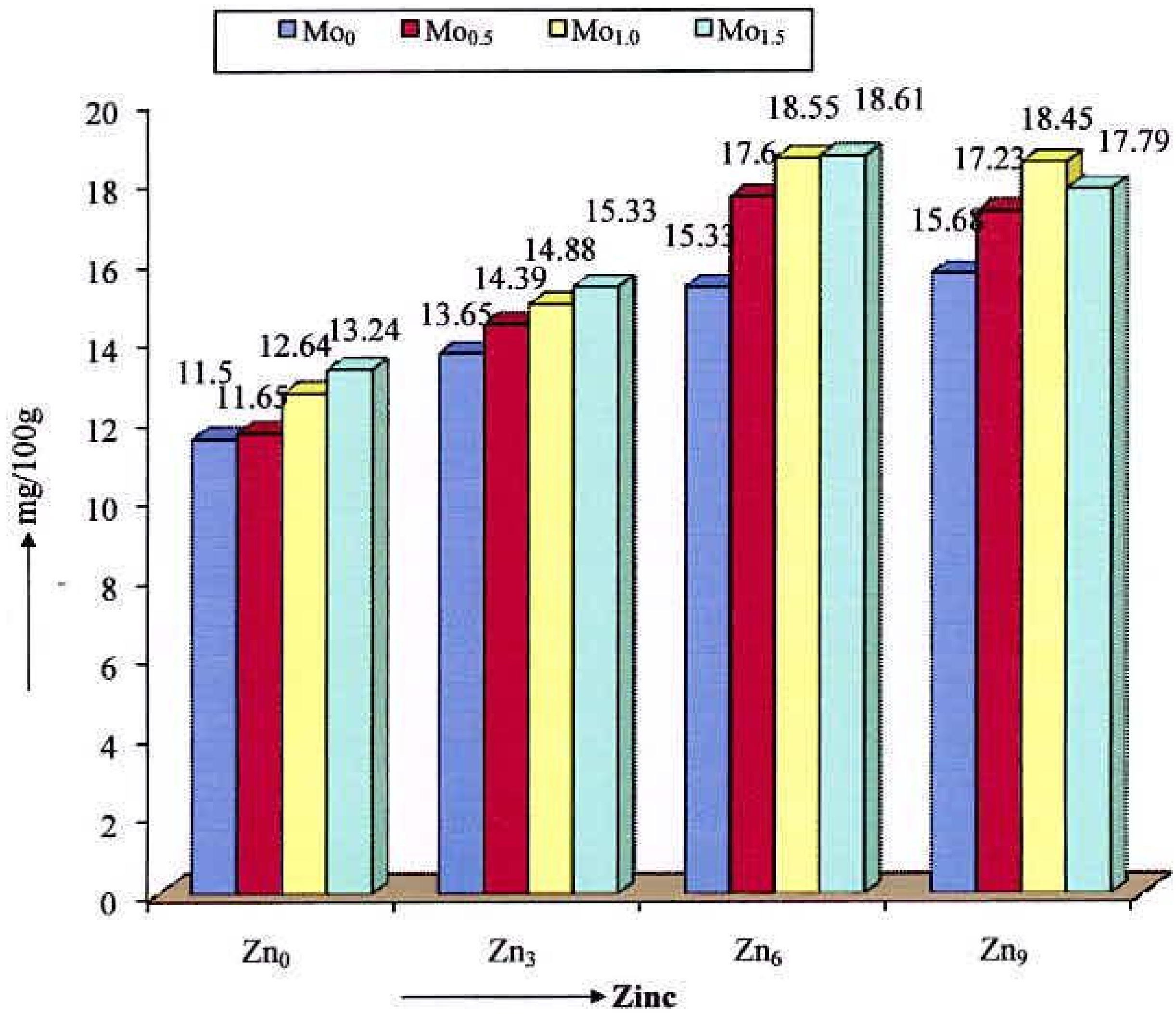


Figure 4: Interaction effect of zinc and molybdenum on vitamin-C of tomato