INFLUENCE OF KAOLIN AND MICRONUTRIENTS ON GROWTH, YIELD AND QUALITY OF SUMMER TOMATO AT DIFFERENT MOISTURE LEVELS

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CERTIFICATE

This is to certify that the thesis entitled **"INFLUENCE OF KAOLIN AND MICRONUTRIENTS ON GROWTH, YIELD AND QUALITY OF SUMMER TOMATO AT DIFFERENT MOISTURE LEVELS"** submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Horticulture**, embodies the result of a piece of *bona fide* research work carried out by *SHARMIN AKTAR*, Registration No. **10-04081** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: December, 2015
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TO

MY BELOVED PARENTS

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ABSTRACT

A pot experiment was carried out at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka during the period from May 2015 to October 2015. The experiment consisted of two factors: Factor A: moisture levels; I_0-100% ET (evapotranspiration) moisture, I_1- 80% ET moisture and I_2-60% ET moisture and Factor B: foliar application of kaolin and micronutrients; F_0-control (spraying tap water only), F_1: spraying of kaolin 2% solution and micronutrients (B, Mn & Se) @ 50 ppm for each of the nutrient solution. F_2: spraying of kaolin 4% solution and micronutrients (B, Mn & Se) @ 100 ppm for each of the nutrient solution. The two factors experiment was laid out in Complete Randomized Design with three replications. Application of kaolin and micronutrients at different moisture levels showed significant variations on most of the parameters. In the case of moisture levels effect, I_1 provided the maximum yield (1.21 kg/plant) with improved color and texture. Regarding foliar treatment of kaolin and micronutrients, F_2 provided the maximum yield (1.18 kg/plant) and better quality. The maximum growth, yield (1.43 kg/plant) and best quality (rich in Vitamin-C and TSS) tomato was found from the treatment combination I_1F_2.

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CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum*) is one of the most popular vegetable crops all over the world. It is a flowering plant belongs to the family Solanaceae. Tomato is the rich source of vitamin-A, vitamin-C and minerals and it keeps eye sight good. Tomato contains lycopene pigment which is a vital anti-oxidant that helps to fight against cancerous cell formation as well as other kind of health complications and diseases (Kumavat and Chaudhari, 2013). A single tomato can provide 40% of the daily requirement of vitamin-C which is a natural anti-oxidant. Tomatoes are rich with vitamin-K which plays a major role in blood clotting. From March to September, tomatoes are practically not grown in Bangladesh due to the weather of tropical region which has characterized by hot and humid condition. But, in this period, the country has imported tomatoes every year from other country. High temperature like as tropical region and heavy rainfall (humid condition) is one of the major problems of unfruitfulness for summer tomato production in Bangladesh. High temperature is responsible to limit fruit set due to an impaired complex of physiological process in the pistil, which results in floral or fruit abscission (Mulholland *et al*., 1999). High temperature adversely affects on tomato physiology and quality attributes, resulting fruit quality defects, uneven ripening and significantly increased commercial damage (Mulholland *et al*., 1999). The plants grown under high daily average air temperature early in the season had lower fruit yield late in the season (Papadopoulos and HaoXiuMing, 2001).

Exposure to higher than optimal temperatures reduces yield and quality of tomato fruit (Adams *et al*., 2001; Dorais *et al*., 2001; Sato *et al*., 2001; Dumas *et al*., 2003). Kaolin- based particle film may be used to mitigate the negative effect of heat stress on plant physiology and productivity (Cantore *et. al*., 2009).

Water supply is another important factor which may greatly affect yield and quality of summer tomato. In Bangladesh, lack of moisture and drought resistant cultivars are the central problems for tomato cultivation. In summer season with high temperature, flower abortion occurs and fruits drop frequently, which causes very poor yield of tomato. For this reason, farmers are not interested in cultivating tomato, especially in the summer season. In our country, it is necessary to produce maximize yield and profit from unit area by using available water efficiently because the existing agricultural land and moisture water are rapidly diminishing (Ibrahim *et. al*.,2010) Therefore, it is essential to balance water requirement, water consumption and yield of summer tomato.

Consequently, it is important to find ways by which available water could be economically utilized. One way to achieve this goal is to reduce the transpiration rate. Using anti-transpirant like kaolin may reduce transpiration rate from the plant; consequently reduce the amount of used water and improve the water use efficiency while it will not reduce carbon assimilation (Nakano and Uehara, 1996; Glenn and Puterka, 2005; Cantore *et al*., 2009). Kaolin is a non- abrasive, non-toxic aluminosilicate [$Al_4Si_4O_{10}(OH)_8$] clay mineral. Kaolin was found to decrease leaf temperature by increasing transpiration rate more than photosynthesis in plants grown at high solar radiation levels (Nakano and Uhera, 1996).

At the same time, it forms a barrier coating on crops that acts as a physical barrier between pest and its host plant (Engelhard Surround® WP Crop Protestant product label; Kerns and Wright, 2001; Glenn and Puterka, 2005). The use of kaolin-based particle film technology would be an effective tool to alleviate heat stress and to reduce water stress in tomato production under arid and semi-arid condition (Cantore *et al.*, 2009). Studies conducted on tomato have shown that foliar applications of kaolin particle films reduce plant stress, which is important for optimum plant growth, yield and quality (Anwar, 2005; Pace *et al*., 2007). However, Kaolin based particle used as an antitranspirant reduced plant and fruit inner temperature and increased marketable fruit yield (Cantore *et al.,* 2009) and kaolin based particle increased the water use efficiency by regulating stomatal movement (Mofta *et al*., 2002) as the experiment was conducted under rain protected condition and 80% water was added to the plant. When tomato products are heat processed, the bioavailability of the lycopene actually increase rather than the anticipated decrease. In addition, kaolin treatment increased lycopene content in fruits. (Cantore *et al*., 2009).

Growers in some countries are commercially producing tomatoes at higher temperature through exogenous application of synthetic hormones. In recent-past, a large number of investigators have studied the effect of various micronutrients on vegetative and reproductive parameters including deficiency symptom and fruit setting. However, foliar application of different micronutrients have some positive effects on tomato plant morpho-phyisological charecters like plant height, leaves per plant, number of flower cluster, fruit set etc.(Sajid *et al*., 2008).

Micronutrient application reduces number of days to fruit-set and significantly increased fruit-set percent, fruit number per plant, and fruit size therefore marketable fruit yield (Makoto, 2000).

Application of Boron (B) promotes the receptivity of stigma by extending the time of pollination and makes viable the pollen resulting higher fertilization and fruit setting. Application of B increased fruit firmness which increased shelf life of tomato (Abdur *et al*., 2009-10), increase fruit sets per plant, increase individual fruit weight per plant and increase brix % in tomatoes. The visible effects of low manganese (Mn) deficiency are pronounced on middle leaves; under acute deficiency condition significant decrease in the concentration of ascorbic acid, soluble proteins, starch, sugars and high phenols reflect poor quality of tomato fruits under manganese deficiency (Dube and Chatterjee, 2001). Application of selenium (Se) had positive effects on the chemical composition and antioxidant constituents of tomato (Schiavon *et al*., 2013). So, application of Se enriches the fruits chemical composition of tomatoes which are beneficial for human health.

Foliar feeding is the best way for summer tomato production (Trejo *et al*., 2007; Sajid *et al*., 2013), resulting higher yield as well as higher income from per unit area of land. Summer tomato in Bangladesh is a high value crop which ensures higher income from per unit area of land (Karim *et al*., 2009; Zaman *et.al* (2006)).

Moisture is a costly agricultural input, so its judicious application is necessary. Deficit water application could help not only in reducing production costs, but also in conserving water and minimizing leaching of nutrients and pesticides into ground water. With this view, it was felt necessary to study the response of tomato plants to both quantitative and temporal variation in soil moisture. By restricting moisture at a non- susceptible phenological stage it may be possible to reduce moisture water quantity and increase water-use efficiency (WUE). In crops, water stress has been associated with reduced yields and possible crop failure. The effects of water stress however vary between plant species.

The experiment may inspire the growers to cultivate summer tomato commercially as well as to improve health and economic status of peoples of Bangladesh. Our initiative was to use some elements such as kaolin as an antitranspirant which is non-toxic clay particle “aluminosilicate” [$Al_4Si_4O_{10}(OH)_8$] and micronutrients ‘B’ as Boric Acid (H_3BO_3), ‘Mn’ as Manganese Sulphate ($MnSO_4$), ‘Se’ as Sodium Selenate and under different moisture regimes by which we can improve the growth, yield and quality by regulating or reducing the adverse effect of high temperature and increased fruit setting of the tomato plant.

However, considering the above circumstances, the present study was under taken with the following objectives:

- To determine the effect of kaolin and micronutrients on the growth and yield of summer tomato.
- To know the morpho-physiological parameters at different moisture levels.
- To find out the effect of kaolin & micronutrients to minimize adverse effect of heat and water stress of summer tomato.

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the most important and widely used vegetables worldwide. The production level of summer tomato never meets the demand of Bangladesh. A large quantity is needed to import every year which may lead the process of losing foreign currency and reserve. Moreover, rising high temperature lead the loss of production. Many researchers have conducted their research on anti-transpirants, micronutrients and the effect of different moisture levels in crop. However, in this chapter, literature available in this aspect in the country and abroad is reviewed.

2.1. Review in relation to foliar application of kaolin

Due to the superiority of kaolin particle film in regulating plant performance and chemistry, it is recommended to be used for reducing water loss by plants in Al-Qassim region, Saudi Arabia. Yuly *et al*. (2011) had carried out a field experiment to know the effect of kaolin film particle application and water deficit on physiological characteristics in rose cut plants. They have studied of foliar applications of a kaolin clay particle film (Surround WP) on leaf temperature, chlorophyll content, shoot length, production and water relations in well-irrigated and water-stressed rose cut plants during ten weeks. Plants were sprayed twice at first and fifth week after the experiment started with aqueous suspensions of kaolin (Surround) at a dose of 5% (w/v). Water stress decreased the stomatal conductance, leaf water content (LWC), shoot length and the number of marketable floral stems. Kaolin sprays affected on SPAD readings, chlorophyll fluorescence, stomatal conductance, LWC and shoot length. Kaolin reduced leaf temperature by 2.5˚C approximately at midday compared to plants non-sprayed with kaolin.

These results show that kaolin foliar applications could be considered a useful tool at early growth stage in improving rose plant acclimation to high temperatures levels under greenhouse conditions in tropical regions.

Ibrahim and Selim has conducted a field experiment at a private farm near Mansoura city, Dakahlia Governorate, Egypt during two summer seasons (2008-2009) to study the effect of moisture intervals and antitranspirant (Kaolin) on summer squash (*Cucurbita pepo* L.) growth, yield, quality and economics. They exposed the plant at three moisture intervals (8, 12 and 16 days, from first moisture) and spraying kaolin at (0.3 and 6%) as antitranspirants at 25, 40 and 55 days from planting and their interactions on growth, yield, fruit quality and water use efficiency of summer squash cv. Eskandrani. Result indicated that moisture every 8 days throughout growing season resulted in highest foliage weight, leaves weight per plant, mean fruit weight, total fruit yield per feddan, marketable yield per feddan and seasonal applied water in both summer seasons. On the contrary, increasing moisture intervals from 8 up to 16 days caused significant increases in leaves dry matter percentage, total soluble solids and dry matter percentage in fruits and water use efficiency in both seasons. The highest net return was observed with plants watered every 8 days and received kaolin at 6% concentration followed by watered every 12 days and received kaolin at 6% concentration that had higher benefit: cost ratio.

From the economic and nutritional point of view, they have concluded that moisture every 12 days intervals combined with spraying kaolin at 6% concentration to summer squash cv. Eskandrani produced satisfactory and good quality marketable fruit yield under similar conditions of this work.

Cantore *et al.* (2009) has conducted a field experiment on kaolin–based particle film technology affects tomato physiology, yield and quality. They summarized environmental stress can affect development plant yield of tomato.

This study was undertaken to investigate the underlying mechanism asserted by kaolin on tomato physiology by evaluating its effect on inner fruit temperature, gas exchange at the leaf and canopy scales, above ground biomass, yield and fruit quality. The study was carried out under field conditions in Southern Italy. Treatments were plants treated with kaolin-based particle film suspension and untreated plants (control). They have found that inner fruit temperature of kaolin treated plant 4.4℃ lower than the control. Marketable yield of kaolin-treated plants were 21% higher than those measured in control plants. Kaolin treatment increase lycopene fruit content by 16% and affect total soluble solids contents, fruit dry matter, juice, titratable acidity or tomato fruit firmness. The use of kaolin-based particle film technology would be an effective tool to alleviate heat stress and to reduce water stress in tomato production under arid and semi-arid conditions.

Mofta and Al-humaid, (2002) had conducted an experiment to examine the effects of different types of antitranspirants (ATs), kaolin and vapor Gard, on vegetative growth, flowering, and chemical composition, of tuberose (*Polianthes tuberose* L.) cv. They have concluded that the performance of kaolin was more effective than that of vapor gard (VG). This might be contributed to its mechanism in reducing leaf temperature, transpiration rate, improvement of plant water status and maintaining biomass production of tuberose plants.

2.2. Review in relation to the application of micro nutrients

Roosta and Hamidpour (2013) was conducted an experiment to evaluate the effects of foliar applications of some micro and macro-nutrients on mineral nutrient content of tomato leaves and fruits through an aquaponic system in comparison with a hydroponic system. Fourteen days old tomatoes seedlings were transplanted in growing bed of aquaponic and hydroponic systems. Foliar nutrients application began 30 days after transplantation. Eight treatments were used, untreated control and foliar application @ 250 mL −with 0.5 g −potassium sulfate (K2SO4), magnesium sulfate (MgSO4 7H2O), ferrous (Fe)-ethylenediamine-N,N'-bis (EDDHA), manganese sulfate (MnSO4 H2O), boric acid (H3BO3), zinc chloride (ZnCl2), and copper sulfate (CuSO4 5H2O). Foliar application of potassium (K), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) increased their corresponding concentrations in the leaves of aquaponic-treated plants. On the other hand, foliar spray of K, Fe, Mn, Zn, and Cu caused a significant increment of applied element concentrations in the fruits of hydroponic-grown plants. These findings indicated that foliar application of some elements can effectively alleviate nutrient deficiencies in the leaves of tomatoes grown on aquaponics.

Schiavon *et al.* (2013) has conducted a field experiment to evaluate the impact of selenium on chemical composition and antioxidant constituents of tomato. They have concluded in such a way, although selenium (Se) is a known anticarcinogen, little is known regarding how Se affects other nutritional qualities in crops. Tomato (Solanum lycopersicon) was supplied with 0-50 micro M selenate and analyzed for elemental composition and antioxidant compounds. When supplied at low doses (5 and 10 micro M) via the roots, Se stimulated the synthesis of phenolic compounds in leaves and reduced the levels of Mo, Fe, Mn, and Cu in roots.

At higher doses (25 and 50 micro M Se) leaf glutathione levels were 3-5-fold enhanced. Supply of selenate via foliar spray (0, 2, or 20 mg Se per plant) resulted in Se-biofortified tomato fruits, with Se levels low enough not to pose a health risk. The Se-biofortified fruits showed enhanced levels of the antioxidant flavonoids naringeninchalcone and kaempferol and a concomitant decrease of cinnamic acid derivatives. Thus, tomato fruits can be safely enriched with Se, and Se biofortification may enhance levels of other neutraceutical compounds.

Sivaiah *et al*. (2013) was conducted field experiment during rabi-2010 to find out the response of foliar application of micronutrients on vegetative and reproductive growth attributes, in two varieties of tomato viz-UtkalKumari and Utkal Raja. The treatments consisted of boron, zinc, molybdenum, copper, iron, manganese, mixture of all and control and the experiment was laid out in RBD with three replications. All the Micronutrients except manganese at 50 ppm were applied at 100 ppm in three sprays at an interval of ten days starting from 30 days after transplanting. All the treatments resulted in improvement of plant growth characteristics viz. plant height, number of primary branches, compound leaves, tender and mature fruits per plant in both the varieties out of which application of micronutrients mixture showed the maximum effect. In tomato cv. UtkalKumari, maximum growth rate (85.7%) was observed with application of zinc, followed by application of micronutrients mixture (78.2%) and boron (77.5%). Tomato cv. Utkal Raja, maximum increase in branches per plant was observed with the application of manganese (148.7%) followed by micronutrient combination (144.1%). In UtkalKumari, the fruit yield per plant ranged from 1.336 kg to1.867 and in Utkal Raja, it ranged from 1.500 kg to 1.967 kg. In both the varieties, combined application of micronutrients produced the maximum fruit yield followed by application of boron and zinc.

Naz *et al*. (2012) conducted an experiment to study the effect of boron on the growth and yield of Rio Grand and Rio Figue cultivar of tomato at Horticultural Research Farm, NWFP Agricultural University, Peshwar during 2008-09. They used different doses of B (0, 0.5, 1.0, 2.0, 3.0 and 5.0 kg ha-1) with constant doses of nitrogen, phosphorus and potash was incorporated at the rate of 150, 100 and 60 kg ha-1. Boron showed a significant effect on the growth and yield of tomato. In the experiment 2 kg B ha-1 resulted in maximum numbers of flower clusters per plant, fruit set percentage, total yield and total soluble solid. Rio Grand cultivar of tomato showed significant effect on all parameters. Maximum number of flower clusters per plant, fruit set percentage and total yield were recorded with Rio Grand cultivar of tomato. They have further mentioned that 2 kg B ha-1 significantly affected flowering and fruiting of Rio Grand cultivar.

Yunaxin and Junhua (2011) conducted some experiments in a perlite bag culture under nutrient drip moisture to study the effects of different concentrations of the trace elements boron and manganese on the yield, fruit quality and antioxidative capacity in tomato. The study showed that under reduced concentrations of boron, tomato yields and the antioxidative content in tomato were significantly reduced. Under high boron concentrations yields and the antioxidative capacity were increased however the ascorbic acid content was reduced. Similarly, under low manganese both yields and the total antioxidative capacity were reduced, however under high manganese levels, yields were not reduced nor were the concentration of ascorbic acid. Total solids were reduced under a high concentration of the micronutrient manganese.

Salam *et al*. (2010) conducted an experiment at the vegetable research farm of the Horticulture Research Centre, Bangladesh Agricultural Research Institute, Joydevpur, Gazipur during the period 2006-2007 to investigate the effects of boron and zinc in presence of different level of NPK fertilizers on quality of tomato. There were twelve treatment combination which comprised for level of boron and zinc viz., i) B0Zn0 - 0 kg B + 0 kg Zn/ha ii) B15Zn20 - 1.5 kg B + 2.0 kg Zn/ha iii) B20Zn40 - 2.0 kg B + 4.0 kg Zn/ha iv) B25Zn60 - 2.5kg B + 6.0 kg Zn/ha and three levels of NPK fertilizers viz., i) 50% less than the recommended NPK fertilizer dose (50%< RD), ii) Recommended NPK fertilizer dose (RD), iii) 50% more than the recommended NPK fertilizer dose

(50% >RD). The highest pulp weight (88.14%), dry matter content (5.34%), TSS (4.50%), ascorbic acid (10.95mg/100gm), lycopene content (112.00 μg/100gm), chlorophyll-b (56.00 μg/100g), marketable fruits at 30 days after storage (67.48%) and shelf life (16 days) were recorded with the combination of 2.5 kg B + 6 kg Zn/ha and recommended dose of NPK fertilizers (N - 253. P - 90 Kg and K - 125kg/ha).

Naga Sivaiah *et al*. (2010) has conducted a field experiment during spring to find out the response of foliar application of micronutrients on vegetative and reproductive growth attributes, in two varieties of tomato viz- UtkalKumari and Utkal Raja. The treatments consisted of boron, zinc, molybdenum, copper, iron, manganese mixture of all and control and the experiment was laid out in RBD with three replications. All the micronutrients except manganese (at 50ppm) were applied at 100ppm in three sprays at an interval of ten days starting from 30 days after transplanting. All the treatments resulted in improvement of seed yield, 100 seed weight, seed yield per plant in both the varieties.

In both the varieties, application of micronutrients mixture reached the maximum seed yield followed by boron treatment; in respect both the parameters, while the lowest yield was obtained in the control.

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

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

Huang and Snapp (2009) was conducted was a field experiment to evaluate the effects of K and B on yield and quality of fresh market tomatoes cv. "Mountain Spring" at Southwest Michigan with well-drained soil (Alfisol Hapludalf, Oakville fine sand). Treatments applied during fruit development included three fertigation regimes (1 N: 0.8K, 1N:1.7 K and 1N: 2.5K) in the presence and absence of a weekly foliar spray of B (300 mg). Increasing K concentrations in the fertilizer increased K content in leaf tissue, but in some cases reduced tissue calcium (Ca) and B. Fruit quality was influenced by nutrition, as the greatest rate of K was associated with increased crack susceptibility as indicated by a fruit bioassay and a 14% increases in incidence of the defect "shoulder check" in field-grown fruit compared to less rates of K nutrition. Boron foliar spray increased tomato marketable yield and fruit quality, reducing shoulder check incidence by 50% compared to zero-B treated plants in 2003. Because of yield and quality improvements, B was a cost effective treatment as shown by partial budget analysis, where as increasing K nutrition did not provide consistent economic benefits. Moderate K rates were associated with the greatest marketable yield, and the 1N: 1.7 K plus foliar B nutrient regime produced the greatest quality fruit. Overall data were consistent with the need of carefully evaluate K and B nutrition in tomatoes, in the context of soil type, yield potential, fruit quality and nutrition regime.

Patil *et al.* (2008) conducted a field experiment to study the effect of foliar application of micronutrients on growth and yield of tomato (Megha) during 2005-06 and 2006-07 at the All India Coordinated Vegetables Improvement Project (AICVIP) in the University of Agricultural Sciences, Dharward. The results based on two years mean revealed that out of nine different treatments, the application of boric acid @ of 100 ppm resulted in maximum number of primary branches (18.30), yield per plant (2.07 kg) and fruit yield (30.50 t/ha). Followed by best treatment was the mixture of micronutrients (B, Zn, Mn and Fe @100 ppm and Mo @50 ppm) recording fruit yield of 27.98 t/ha and differed significantly from the control as well as other treatments.

The maximum benefit ratio of 1.80 was obtained with application of boron recording Rs 97.850/ha of net returns followed by the mixture of micronutrients (1.74) recording (1.74) recording Rs 88.900/ha net returns compared to control (1.40) which recorded minimum net returns of Rs 53.250/ha.

Trejo *et al.* (2007) was conducted a field experiment to evaluate the effect of such foliar fertilizer on fruit quality of tomato (*Lycopersicon esculentum* var. floradade), plants were grown on an alkaline soil (pH 8.1) containing low concentrations of available micronutrients. The experiment was conducted under greenhouse conditions in a random array with four replications per treatment. The treatments evaluated were: (1) control, (2) soil fertilizer application (N-P-K at 150-60-00 kg/ha) and (3) a combination of soil fertilizer application with foliar applications of micronutrients (sprayed once a week). Twelve foliar applications were carried out during the experiment. Electrical conductivity (EC), PH, Brix value (degrees Brix) and titrable acidity (TA) were measured to evaluate fruit quality while foliar analysis of micronutrients was carried out in order to establish the nutrient status of leaves. Data were statistically analysed using ANOVA, orthogonal contrast and Tukey's tests. Positive effects of foliar fertilization as a complement of soil fertilization were observed on TA (approximately 27 and 75% higher than the control and soil fertilization, respectively) and degrees Brix (about 25 and 55% more than control and soil fertilization, respectively). Micronutrient concentration in leaf was increased as a result of foliar fertilization as well. They have concluded that foliar fertilization is appropriate to feed tomato plants in alkaline soils, resulting in better micronutrient status of plants and higher quality of fruits.

Basavarajeshwari *et al.* (2005-07) carried out a field experiment to study the effect of foliar application of micronutrients on growth and yield of tomato at the all Indian Coordinated Vegetables Improvement Project (AICVIP) in the University of Agricultural Sciences, Dharwad.

The result based on two years mean revealed that out of nine different treatments, the application of boric acid @ of 100 ppm resulted in maximum number of primary branches (18.30), yield per plant (2.07 kg) and fruit yield (30.50 t/ha). Followed by the best treatment was the mixture of micronutrients (Bo, Zn, Mn and Fe 100ppm and Mo @ 50ppm recording fruit yield of 27.98 t/ha and differed significantly from the control as well as other treatments.

Alvarez *et al*. (2005) studied and experiment with deficient to toxic levels of Mn and B, the absorption and distribution of Fe in tomato plants (*Lycopersicon esculentum*, Var. Marglobe), grown hydroponically in a green house and B was added to disturb growth and hence nutrient demands. The experiment reveals that deficient or normal Mn levels antagonize Fe absorption, but the reverse was true when Mn reached toxic values; nevertheless, Mn effect was always antagonistic on Fe transport. From the above-related results, together with P and Ca absorption and distribution, they suggested that Mn/Fe in the shoot is not related at all with plant growth. B levels influence Fe absorption and translocation paralleling the dry matter production.

Naresh Babu (2002) was carried out an investigation in Nagaland, India during 1998-2000 to determine the effects of foliar application of boron (50, 100, 150, 200, 250 and 300 ppm) on the growth, yield and quality of tomato cv. Pusa Ruby. Boron improved the yield and quality of the crop. The highest yield (327.18 and 334.58 q/ha) was obtained when the plant was drenched with 250 ppm aqueous solution of boron. B also had positive effects on plant height, number of branches, flowers and number of fruit set per plant, resulting in an increase in the number of fruits per plant and total yield. At lower rates, B improved the chemical composition of tomato fruits and at higher rates increased the total soluble solids, reducing sugar and ascorbic acid contents of the fruits. He has concluded that acidity of fruits showed a marked increase with increasing levels of B up to 250 ppm.

Chude *et al*. (2001) showed that B deficiency on crop field led to reduction in yield of crops. They further mentioned that application of compound fertilizer (NPK) mixed with B fertilizer increased the yield of tomatoes. Sobulo (1975) obtained the highest yield of tomato when a mixture of NPK and 0.01% borax was applied compared with mixtures of NPK and other micronutrients.

Dube and Chatterjee (2001) conducted an experiment to study manganese deficiency effects in tomato (*Lycopersicon esculentum*) var. Pusa Ruby where plants were grown in refined sand at two deficiencies i.e. 0.0011 and 0.055 mg/L and one adequate 0.55 mg/L levels of manganese. Manganese deficiency at 0.0011 mg Mn/L reduced the fruit yield more than the biomass. At low management levels, the concentrations of Mn, chlorophyll, starch, hill activity and acid phosphatase were decreased, whereas the concentration of sugars, activity of peroxidase, catalase and ribonuclease were increased significantly in tomato leaves. The visible effects of low manganese deficiency were pronounced on middle leaves under acute deficiency condition i.e. at 0.0011 mg MN/L. A significant decrease in the concentration of ascorbic acid, soluble proteins, starch, sugars and high phenols reflect poor quality of tomato fruits under manganese deficiency.

Makhan *et al*. (1999-2000) has conducted a field experiment for the response of foliar application of micronutrients on tomato variety at Vegetable Research Farm and Laboratory of CCS Haryana Agricultural University. The experiment was laid out randomized block design with three replications consisting of eight treatments of micronutrients and control making a total nine treatments. The treatments were ammonium molybdate, borax, copper sulphate, ferrous sulphate, manganese sulphate, zinc sulphate, mixture of all micronutrients and control. The micronutrients were applied as foliar spray @5 g per liter (0.5%) at the interval of ten days i.e. 40, 50, 60 days after transplanting. Mixture was made by taking all the micronutrients in equal proportion i.e. 0.83 g and mixed thoroughly.

Five weeks old seedlings were transplanted for the experimentation.The result indicates that application of all the micronutrients, significantly enhanced plant height over control. Highest increase in plant height (54.80 cm) was recorded with application of micronutrients.

Boron is an essential micronutrients required for normal plant growth and development. It performs a wide range of functions in tomato plants. It is a very sensitive element and plants differ widely in their requirements but the ranges of deficiency and toxicity are narrow. It maintains a balance between sugar and starch in plant body. It translocates sugar and carbohydrates in different parts of the plant body. It is important in pollination and seed production. It is necessary for normal cell division, nitrogen metabolism and protein formation. It is essential for proper cell wall formation. Boron plays an important role in the proper function of cell membranes and the transport of K to guard cells for proper control internal water balance. The requirement of B in vegetables generally more than other crops.

Paithankar *et al.* (1994-95) was conducted a field trial at the main garden of the Department of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India in a randomized block design with 16 treatments and three replications to evaluate the effect of boron and diammonium phosphate (DAP) on the quality and performance of tomato. Foliar sprays of 0.1, 0.2 and 0.3% borax as well as 1, 2 and 3% DAP were given each alone and in combination at 60 days after transplanting. They have conclude that Borax at 0.3% provided the maximum fruit size and ascorbic acid content and the 0.3% borax + 3% DAP treatment recorded the maximum total soluble solids. The treatment 0.3% borax + 2% DAP reduced the cracking of fruits.

2.3 Review in relation to the effect of moisture on the yield attributes of tomato

Sharma *et al.*, (2007) conducted a study to investigate the effect of drip moisture and different kinds of mulches on fruit yield, quality and water-use efficiency of strawberry cv. Chandler. Berry yield was significantly higher under the treatment of drip moisture at 100 per cent of evaporation + black polyethylene mulch (78.6 q/ha) whereas lowest yields (12.13 q/ha) were recorded in non-irrigated treatment (rainfed + un-mulched control). Berry weight, volume and size were the maximum in drip moisture with 'V' volume +hay mulch treatment. Berry weight and berry volume in drip moisture with 'V' volume+ hay mulch treatment were found to be higher by 75.50 and 43.50 per cent respectively, than the treatment rainfed+ hay mulch. Sugar and anthocyanin content of strawberry were also maximum in drip moisture, 'V'+ hay mulch treatment, followed by drip moisture 0.8'V'+ hay mulch treatment whereas, lowest values were observed under rainfed+un- mulched treatment. However, TSS and acidity values were higher by 12.45 and 29.12 per cent, respectively under rainfed+ un-mulched treatment over the drip moisture, 'V'+ hay mulch treatment being the minimum in TSS (7.66%) and acidity (0.73%) values. Highest water-use efficiency (1.27 q ha^{-1} cm^{-1}) was recorded under the treatment drip moisture at 60 per cent of evapotranspiration + black polyethylene mulch which was 269.9 per cent higher than the lowest water-use efficiency (0.36 q ha^{-1} cm^{-1}) recorded under the rainfed + un- Accurate estimation of water consumption by plant is important not only in directing moisture and improving water use efficiency of crop, but also in studying the interactions between plant and atmosphere (Wang *et al.,* 2006).

Vazquez *et al.,* (2006) and Begum *et al.,* (2001) reported that water deficiency enhanced the flower-dropping and fruit- dropping, which may be contributed to have minimum number of fruits per plant in minimum moisture treatment.

High tomato yield with moisture was also showed by Vazquez *et al.,* (2006). High water use efficiency in minimum moisture levels may produce substantial yield with minimum water use. The results resembled the findings of Begum *et al.,* (2001).mulched control.

Zhang *et al.,* (2005) showed high grain yield of wheat growing in straw mulch with moisture. He also said that adopted straw mulch was adopted as water-saving measure. They showed significantly improved WUE (Water Use Efficiency) by 8 to 10 % due to application of mulch.

Kanthaswamy *et al.,* (2004) reported that nutrient medium, moisture regime and spacing positively affect the growth, yield and quality of tomato hybrid SH 7611 which resulted with increased fruit yield with better fruit quality.

Sushant *et al.,* (1999) also evaluated that more fruits obtained in efficient moisture levels in comparison with no moisture. It was reported that 60% water depletion treatment significantly reduced fresh fruit yield compared with the other depletion treatments but did not affect soluble solids concentration. Moisture cut off at 60 days prior to harvest significantly reduced the yield and soluble solids concentration.

As moisture water cost is high and moisture facility is limited to around 30% of the total cultivable land in Bangladesh, it is imperative to use moisture water more wisely to maximize the profit. Tomato is sensitive to water stress (Bose and Som 1986; Begum *et al.,* 2001). She also reported that moisture is indispensable and high frequency of moisture is required for obtaining good yield of tomato in the clay terrace soil of Bangladesh. The percentage of peaceable fruits was significantly higher with moisture cut off at 20 days before harvest (May and Gonzales, 1994).

Mannan and Haque(1999), working on six water regimes on two varieties of cabbage(viz. Atlas-70 and k-k cross), found that 80% F.C. produced the highest plant height, fresh weight of leaves, stems, roots and head thickness and diameter of head and gross marketable yields of cabbage. The driest treatment (40% F.C.) gave the maximum number of loss of leaves per plant and length of roots.

Dadomo *et al.,* (1994) carried out an experiment in tomato with moisture at three rates i.e. 0.5, 0.9 or 1.3 x maximum evapo-transpiration (Max ET). The treatment effects were dependent on the soil and climate in different locations. In general increased moisture had a significant effect on the main yield components.

Tuzel *et al.,* (1994) conducted an experiment in green house tomato scheduled every three days or daily using moisture rates calculated from pan evaporation using four pan coefficients of 0.6,0.8, 1.0 and 1.2. Plant growth and yield was not affected by moisture interval, but the best pan coefficient for maximum early and total yields was 1.2. Similar a pan coefficient of 1.2 produced the greatest early and total yield, but tended to reduce fruit TSS and DM contents.

It was showed by Pemiola *et al.,* (1994) that water stress caused an increase in diffusing resistance compared with the irrigated treatments, whereby the stomata remained almost fully closed most of the time. There was also a corresponding decrease in DM accumulation.

The highest average marketable yield (66.4 ton/ha) was obtained with 100% restoration of Max ET. Restoration of 50% of Max ET resulted in the greatest water use efficiency.

Ramalan and Nwokeocha (2000) conducted an experiment at Research Farm, Institute of Agricultural Research, Samaru, Nigeria to evaluate water management options on the performance of tomato. Moisture of mulch and moisture at the specified suction levels have had influence on growth of tomato. The rice straw mulch on furrows significantly delayed the attainment of 50% fruiting by 6 days compared to the un-mulched plots. Fruit sizes at the ages of 17, 19 and 21 weeks after planting, marketable fruit yield, crop water use and water use efficiency were significantly affected by all the three factors. Fruit weight was affected only by soil water suction.

The interaction of furrow moisture method, mulch and soil water suction had significant effect on water use efficiency (WUE) of the crop. Use of alternate furrow method was statistically at par, in terms of WUE with the conventional furrow method if it was mulched and irrigated at 5-days interval.

Pugalia *et al.,* (1992) described that tomato yield and quality were obtained with sprinkler moisture applied daily from a height of 450-500 mm, fruit length (mm), fruit diameter (mm), fruit weight and yield decreased with the decreasing of moisture levels.

In another study the optimum soil moisture emergence of garlic was found to be 80%-100% of field capacity. Plants grew faster and produced the highest yield when moisture was maintained at 80%-90%. However, keeping quality of the bulbs was poorer than that of plants grown at a lesser soil moisture because of the large cells and thinner cuticle which lead to higher transpiration (Dimitrov, 1974).

Dematte *et al.* (1982) reported that 65 and 80 percent available soil water resulted in appreciable high yield of carrots in sprinkler moisture system. Moisture stress just before harvest restrict the growth and increases the level of dry matter and sucrose content in carrot (Dragland, 1978).

He also reports that no moisture at all decreases yield but increases dry matter, nitrogen and carotene content of the root. In contrary Benga(1963) reported higher carotene content in relatively high soil moisture regime than lower level.

The average moisture application in carrot cultivation should vary from 60to 80mm and at 60percent of field capacity, yield and quality of root increases (Henkel, 1968).

Reduced number of tomato fruits per plant due to water stress was also reported in earlier stage of plant growth (Peterson, 1989).

In Tunisia, Rudich and Luchinsky (1987) demonstrated that the water requirement of tomatoes was affected by rice straw mulch and moisture. They explained that the application of mulch and moisture maintained a favorable soil environment (Ghuman and Lai, 1983).

Lin *et al.,* (1983) reported water use in tomatoes in Taiwan ranged from 280 to 580 mm with corresponding WUE of 2.3 to 1.0 t/ha/cm. However, there was an additional 75-85 mm of precipitation and the water table varied between 1.4 and 1.8 m from the surface, so that, the crop could have extracted some of its water from the soil above the water table. Van Ootegam *et al.,* (1982) studied the response of tomato to water application and concluded that the water requirement of tomato to be 525 mm with the yield of 113 t/ha and WUE of 2.95 t/ha/cm. Doorenbas and Kassam (1979) reported that both excess and shortage of moisture are detrimental to the growth and yield of tomato. They also showed that water stress during the growth stage of plant increases flower-drop and retards fruit-growth.

CHAPTER III

MATERIALS AND METHODS

The pot experiment was conducted at Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka - 1207, Bangladesh in 2015 to determine the growth, yield and quality of summer tomato (BARI-4) as influenced by foliar application of kaolin as an antitranspirant which is non-toxic clay particle "aluminosilicate" ($Al_4Si_4O_{10}(OH)_8$) and micronutrients Zn as Zinc Sulphate ($ZnSO_4$), B as Boric Acid (H_3BO_3), Mn as Manganese Sulphate ($MnSO_4$), Se as Sodium Selenate at different moisture level. This chapter includes a brief description of materials used, treatments, location of the experiment, characteristics of soil, weather & climate and process of experimentations etc.
A brief description of methods and materials are given below:

3.1 Experimental site

A pot experiment was conducted at the horticulture farm of Sher-e-Bangla Agriculture University, Dhaka, Bangladesh during the period from May 2015 to October 2015.

3.2 Location

It was located in 24°09' N latitude and 90°26' E longitudes. The altitude of the location was 8 m high from the sea level (The Meteorological department of Bangladesh, Agargoan, Dhaka).

3.3 Characteristics of Soil

The soil of the experiment was collected from the horticulture farm. The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28. The selected plot of soil was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil used the experiment were analyzed in the Soil Testing Laboratory, Soil Resources Development Institute (SRDI) Farmgate, Dhaka and details soil characteristics were presented in Appendix I.

3.4 Pot soil collection and preparation

The soil was collected one month prior to setting the experiment. The top soil at a 15 cm depth was collected from the horticulture farm area of north-east corner, mixed thoroughly and makes it clean by removing stones, grass, roots and other debris.

3.5 Climate and weather

The climate of the experimental area was sub-tropical in nature. It is characterized by its high temperature and heavy rainfall during kharif season i.e. April to September and scanty rainfall associated with moderate temperature during robi season i.e. October to March (Anonymous, 1989).

3.6 Collection of seeds (planting materials)

The seeds of BARI Tomato-4 were collected from the Horticulture Research Center, BARI, Gazipur-1701, Bangladesh.

3.7 Raising of seedlings

Soil of the seed bed was made loosen and friable as much as possible and organic matter mixed with soil. All weeds, stones and dead roots were removed. The seeds were sown on 5th June 2015 in the raised seed bed of 1m size. The seed bed was supported with partial shed at 1:00-3:00 pm in the high hot day by using coconut leaves. Proper care was taken to raise healthy seedlings.

3.8 Fertilizer application in the pot soil

The collected soil was measured as a cubic meter by applying length (m) × width (m) ×high (m). For field crops, a depth of soil is considered 15 centimeter (0.15m). So, one decimal land is (40.5m^2× 0.15 m) - 6.075 m^3 (approximate) which has considered as a root zone soil. Total volume of collected soil was calculated which has found 14.65 m^3 considering Length 3.5 m × width 3.1 m × height 1.35 m. Recommended fertilizer dose for summer tomato (BARI Hybrid-4) for very low status soil: Organic Matter, Urea (Total nitrogen: minimum 46%), MP (as Muriate of potash: 60% K_2O), TSP (as Triple Super Phosphate: 48% P_2O_5) and Gypsum (as $CaSO_4.2H_2O$ containing 19% S) for one decimal land is 50 kg, 1.6 kg, 0.68 kg, 0.5 kg, and 0.43 kg which has considered for 6.075 m^3 of root zone soil, respectively (Source: FRG 2012). Our total soil volume was 14.65 m^3 and one decimal is equal to 6.075 m^3. So, a comparison was made to estimate the exact amounts of organic matter, MP, TSP and Gypsum which has found $\text{organic matter (OM)} = \frac{50\times14.65}{6.075} = 120.6\ \text{kg}, MP: = \frac{0.68\times14.65}{6.075} = 1.64\ \text{kg},\ TSP = \frac{0.5\times14.65}{6.075} = 1.20\ \text{kg},\ \text{Gypsum}\ \frac{0.43\times14.65}{6.075} = 1.04\ \text{kg},$ respectively. Finally, the calculated amount of organic matter, half of MP and all required TSP and Gypsum were applied prior 21 days of filling the pot with soil. One decimal land can be accommodating 162 plants considering spacing row to row and plant to plant 50 cm × 50 cm. Our total plants under experimentation were 120 which have needed 1185 g of urea for three time of application. Each time @ 3.30 g urea per plant was applied at 10, 25 and 40 days after transplanting as a ring method. Rest half of MP (820 g for 120 plants) was applied in two split dose at 25 and 40 days after transplanting at the time of 2nd and 3rd dose of urea application. Each time @ 3.42 g MP was applied per plant.

3.9 Pot preparation

Plastic pots were used in this experiment. The height and width of each pot was 35 and 30 cm respectively. Two holes were made in the middle of the bottom of each pot and holes were covered by the broken pieces of earthen pot. All the pots were washed with ash and tap water by rubbing and sun dried. The fertilizer mixed soil was made well pulverized and dried in the sun. Final check was made to remove plant propagates, inert materials, visible insect and pests. In the lower part of all the pots were filled with general sun dried and clean soil; only upper 20 cm of the pot was filled with fertilizer mixed well prepared soil and topmost upper 5 cm of the pot was blank for moisture purpose. Gravimetric method was used to find out proper strategy to irrigate pot plants.

In this connection, plastic pot with soil was weighted using weighing balance and all the plastic pot was made in equal weight including soil which was

13.00kg where only empty plastic pot was 1.00 kg. Water was added in each pot to make it well saturated condition. After well saturation of the soil with water it was weighted and found 16.55 kg. So, water required (16.55 – 13) kg - 3.55 kg to make it well saturation. Pot with soil was allowed for two days in normal homestead environment. After two days, the plastic pot with wetted soil was weighted and it was found 14.25 Kg. A difference was made in between pot with wet soil in water saturated condition and pot with soil after allowing two days. So, the loss of water - weight of pot soil in saturated condition – weight of pot soil after allowing two days - 16.55 kg – 14.25 Kg - 2.3 kg. The amount of water lost during the 2 days was recovered completely by moisture, for control pots only. As the experiment was conducted in rain protection measure, strategy was followed to irrigate the pots with 100%, 80% and 60% of the water added to the control plants.

3.10 Transplanting of seedlings in the pot

25 days aged single seedlings were transplanted on 30th June'2015 in the middle of each pot in the late afternoon of the same day. Immediate after transplanting the plants were irrigated with tap water. The pots were arranged inside the polythene shed.

3.11 Treatments of the experiment

The experiment consisted of two factors:

<u>Factor A</u>. Moisture levels

I_0 - 100% ET (Evapotranspiration) moisture

I_1 - 80% ET moisture

I_2 - 60% ET moisture

<u>Factor B</u>: Foliar application of kaolin and micronutrients

i. F_0: Control (Spraying of tap water only).
ii. F_1: Spraying of kaolin as an antitranspirant which is non-toxic "aluminosilicate" [$Al_4Si_4O_{10}(OH)_8$] @2% solution. and B as Boric Acid,

Mn as Manganese Sulphate ($MnSO_4$), Se as Sodium Selenate @ 50 ppm for each of the nutrient solution.

iii. F_2: Spraying of kaolin as an antitranspirant which is non-toxic "aluminosilicate" [$Al_4Si_4O_{10}(OH)_8$] @4% solution and B as Boric Acid, Mn as Manganese Sulphate ($MnSO_4$), Se as Sodium Selenate @ 100 ppm for each of the nutrient solution.

There were 9 (3×3) treatment combinations such as I_0F_0, I_0F_1, I_0F_2, I_1F_0, I_1F_1, I_1F_2, I_2F_0, I_2F_1 and I_2F_2.

3.12 Design and layout of the experiment

The experiment was carried out in a Complete Randomized Design (CRD). The total plants were divided into three groups (100% ET moisture, 80%ET moisture & 60% ET moisture) with 3 replications. Four plants were exposed to each treatment. The distance between two replications and two treatments were maintained 50cm and 2m respectively. Seedlings were planted in the middle of the pot soil. The layout of the experiment is shown in Figure 1.

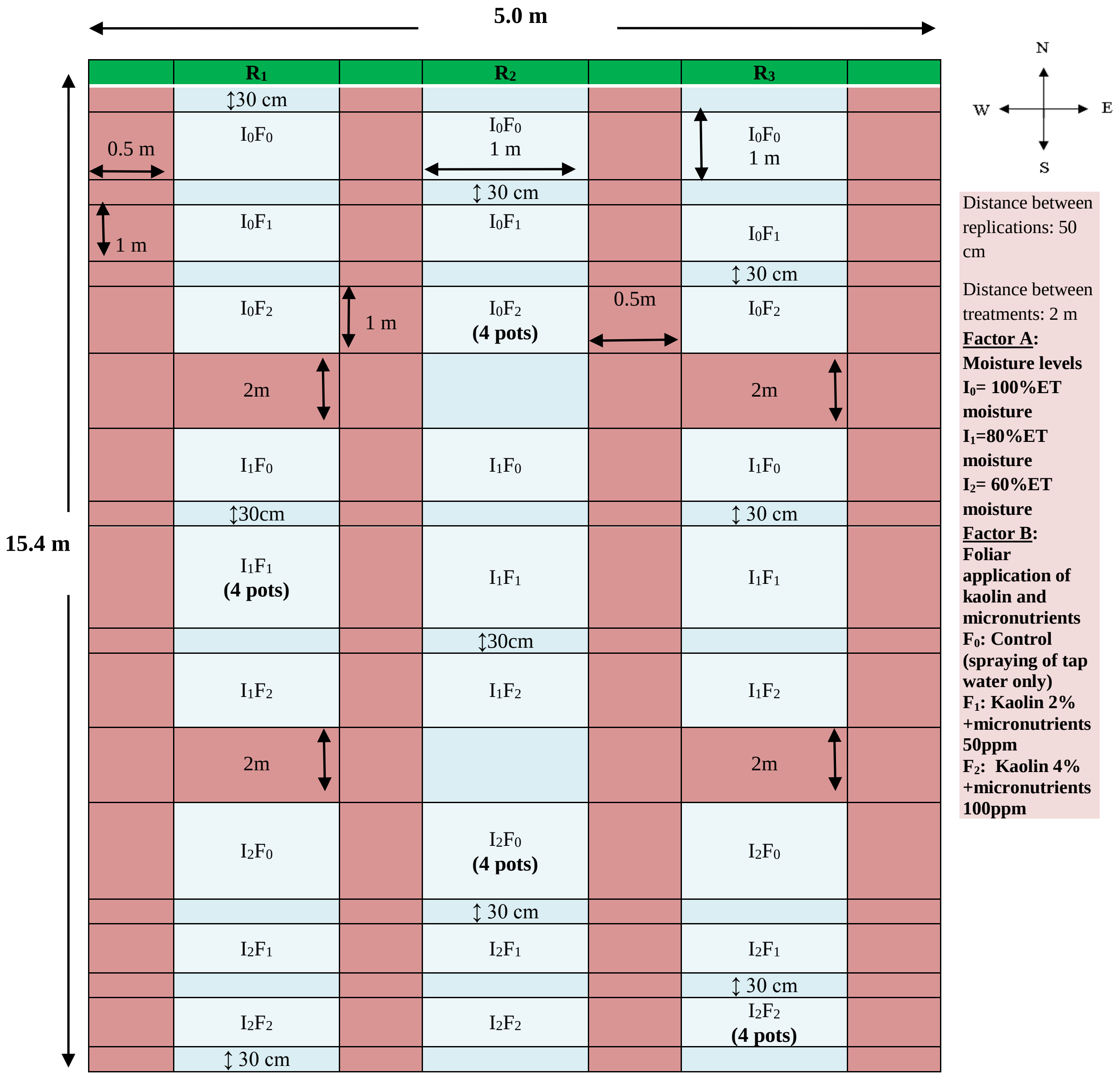


Figure 1: Layout of the experimental plot.

3.13 Intercultural operations

3.13.1 Moisture

Immediate after transplanting, light watering to the individual seedling was provided to overcome water deficit. Plants were irrigated with water at 100%, 80% & 60% level at five days interval.

3.13.2 Supporting

All the plants were supported with bamboo sticks and threads as and when required.

3.13.3 Weeding

Weeding and soil loosening was done as and when required. It was done three times during experimentations.

3.13.4 Pruning

All shoots from the base of all plants were removed at an 8 cm distance from the ground. It was maintained to a single stem by removing all side shoots at least once a week. Remove the shoot early in the morning on sunny days when they are very small (one inch or smaller). The small wound resulting from removing the shoot will heal quickly leaving less chance for fungal invasion.

3.13.5 Urea and MP application

Urea was applied in three times as a ring method at 11, 23 and 45 days after transplanting. MP also applied at 23 and 45 days after transplanting (DAT) together with urea application as per prescription of Olericulture Division, Horticulture Research Centre (HRC), Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh.

3.13.6 Use of pesticide

Admire was sprayed @ 1 ml per liter of water for 3 times at 11, 23 and 45 DAT of seedling in the all plants of the pots to protect the plants from diseases.

3.13.7 Use of fungicide

Ridomil was sprayed @ 1 gm per liter of water for 3 times at 13, 34 and 49 DAT of seedling in the pot soil.

3.13.8 Use of plant growth regulator

4-CPA was applied as growth regulator @ 05 ml per liter of tap water as per commercial formulation and it was applied in the flower and flowering stalk.

3.14 Application of the treatments

All the treatments were applied considering the design of the experiment. First application was made at 25 DAT in the day when first flower initiation was found in the experimental plot. Moisture were given at a 05 days interval upto final harvest. A specific concentration of the each nutrient solution was maintained. All the micro nutrients were made at a 50 ppm and 100ppm separately for each time of the application and it was sprayed on the leaves of the plants. Kaolin 2% and 4% solution was prepared and sprayed on the day after each moisture.

3.15 Data collection

3.15.1 Measurement of plant height

Height of plant was measured with a meter scale from the base of the plant to the tip of the leaf of the main stem for four times. First height was measured at 18 days after transplanting (DAT) before applying the first treatment on the same day. Second, third and fourth plant height was measured at 30, 45, and at the final harvest . All the foliar treatments of growth promoting elements were applied at 15 days interval. The final height was measured at the final harvesting time. The plant height was measured and expressed in centimeter. Recorded data was made an average.

3.15.2 Measurement of foliar coverage

Foliar coverage was measured with a meter scale. It was estimated at the point where the plan was highly covered the area by the expansion of leaves. It was done five times during experimentation. It was measured at 30, 45 DAT and at the day of final harvest.

3.15.3 Measurement the length of internodes

The lengths of internodes of individual plants were measured at the final stage of harvesting. A meter scale used for estimating the length of internodes and expressed in centimeter (cm). Average data was used for statistical analysis.

3.15.4 Counts the number effective fruiting branches

The total number of branches of individual plant was counted by visual observation at the final harvesting of fruits. It was counted above 8 cm from the ground level because branches were removed through pruning practices up to 8 cm from the ground. Recorded data was used to make an average.

3.15.5 Counts the number of leaves

The total number of leaves of individual plant was counted and recorded. It was counted for first time at 45 DAT and the place of each stem was marked with plastic rope to identify the location of counting part of the steam. For the second time number of leaves were counted at the final harvest and it was made an average.

3.15.6 Measurement of length of leaves

The lengths of leaves of individual plants were measured at the final stage of harvesting. A meter scale used for estimating the length of leaves and expressed in centimeter and it was made an average.

3.15.7 Counts the number of fruits clusters per plant

Total number of fruits cluster was counted at the final stage of harvesting for individual plant and treatment. Data were collected and it was made an average.

3.15.8 Counts the number of fruit sets per plant

Fruits were harvested considering commercial maturity stage of fruits. The maturity of the crop was determined on the basis of starting reddish coloring of fruits. The fruits of each pot plant were harvested separately. In each of the harvesting, the number of fruits data was recorded. In case of production sprayed with 4% kaolin and 100ppm micronutrients, the harvesting started on 11 September 2015 (73 DAT) and completed 05 October 2015 (95 DAT).

In case of production sprayed with 2% kaolin and 50ppm micronutrients the harvesting started on 20 September 2015 and completed 10 October 2015.

3.15.9 Measurement of P^H

Two tomato samples were collected from each of the treatment which was fully ripened. Each sample was blended and it was made in liquid form. All the samples were taken in clean and transparent plastic pots. Electric P^H meter (model H 12211 P^H/OPR meter, Hanna Company) was adjusted in buffer solution of P^H7.0; later on again it was adjusted in buffer solution containing P^H 4.0. Finally, Electric P^H meter was inserted in first sample and data was recorded. Again, P^H meter was inserted in buffer solution containing P^H 4.0 to adjust the P^H meter and again it was inserted in second sample of tomatoes and data was recorded. The same procedure was followed to measure P^H of all other samples.

3.15.10 Measurement of total soluble solids (TSS)

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

3.15.11 Measurement of Vitamin-C

Volumetric method is used to measure Vitamin-C or ascorbic acid in per 100 gm of tomato samples. It has expressed as mg Vitamin-C per 100 gm of tomatoes. It was measured in Biochemistry Laboratory of Sher-e-Bangla Agriculture University, Dhaka.

3.15.12 Fruit length

The length of individual fruit was measured in one side to another side of fruit from five selected fruits with a meter scale and average of individual fruit length recorded and expressed in centimeter (cm).

3.15.13 Fruit diameter

The diameter of individual fruit was measured in several directions with meter scale and the average of all diameters were finally recorded and expressed in centimeter (cm).

3.15.14 Measurement of fruit firmness

Force gauge (Yamagata Univ. Japan: FG – 5000A) was used to measure firmness of fruits and it was expressed as Neuton. Tomato sample was collected in full red condition of same physiological stage from each of the treatment to measure firmness. Tomato sample was taken under forced by making pressure by the upper surface of the force gauge and force was applied to know the break point in the scale. Data was recorded three times during experimentation to make an average.

3.15.15 RWC (Relative water content)

Relative water content (RWC) was calculated according to this equation:

RWC- 100 x (FW-DW) / (TW-DW)

Here,

FW- fresh weight of leaf

TW- turgid weight of leaf

DW- dry weight of leaf

The uppermost fully expanded leaves that were detached and weighed (FW), then the leaves floated on distilled water at 22-25^{0}C in a dark chamber for 24 hours and after that leaves were weighed (TW). Dry weight was determined after oven drying at 75^{0}C for 48 hours.

3.15.16 Measurement of leaf temperature

The temperature was recorded using smart sensor infrared thermometer (AR852B$^+$) in degree centigrade (^{0}C) and it was done three times during experimentations.

During measurement of temperature the button of the instrument was pressed and red light was passed on the leaves surface and it was directly showed temperature in degree centigrade (^{0}C). In all the time of recording the temperature, it was estimated in the third day of application of each of the treatment. The day of the recording temperature was fully sunny and data was collected from 1:00 to 2:00 pm for all the day of measurement. Finally, an average was made of the recorded temperature.

3.15.17 Measurement of fruit inner temperature

Smart Sensor (AR 867) was directly inserted in the fruit of each standing plants in field condition. The sharp point was inserted up to one inch and keeps it inside for thirty seconds. Smart sensor was viewed temperature in degree centigrade (^{0}C). Temperature was measured three times during experimentation to make average.

3.15.18 Measurement of canopy temperature

Canopy temperature was recorded by simple thermometer, 18 thermometers were set randomly on selected 18 plants. Data were recorded before and after of each foliar application of the treatments.

3.15.19 Yield (kg) /plant

Fruits were harvested at the commercial maturity stage of fruit. In each of harvesting, the weights of harvested fruits were recorded using electric balance in the field. The final data was made at the final harvesting using calculator and Microsoft Excel Software. Average results are used for statistical analysis purpose.

3.16 Harvesting of tomato

Tomatoes were harvested early in the morning when the fruits were developed red colors (breakers). Always avoided full sunny and hot weather and soon after harvesting fruits were stored at room temperature. A fruit harvested at the red ripe stage will be subjected to more bruising without enhancing quality.

3.17 Statistical Analysis

The collected data were statistically analyzed to find out the level of significance using MSTAT-C software. The significance of the difference among the treatment mean was estimated by Least Significant Difference (LSD) Test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

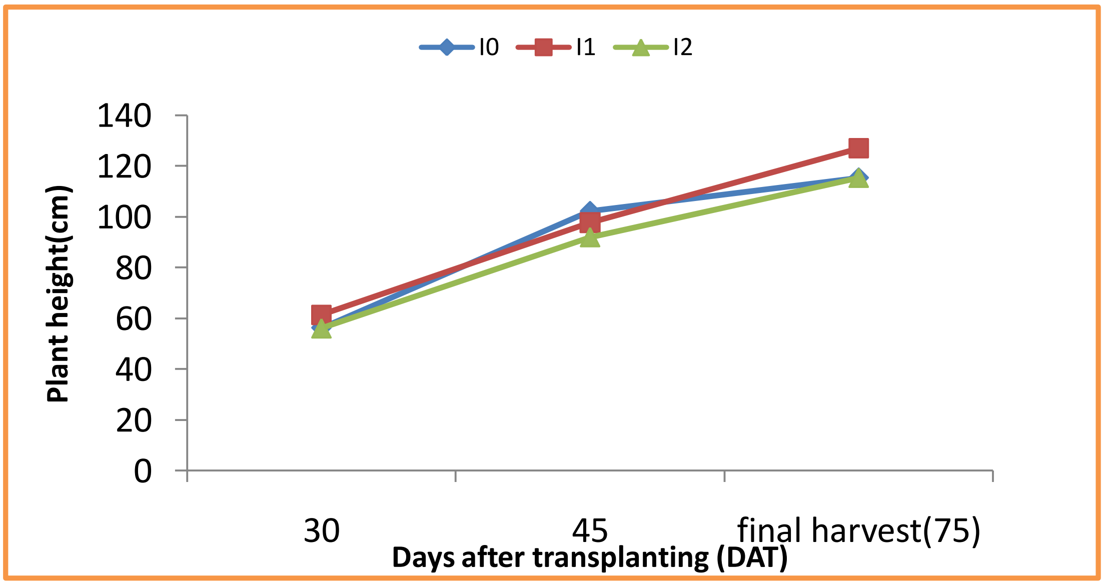
RESULTS AND DISCUSSION

The research work was accomplished to identify the effect of foliar application of kaolin as an antitranspirant which is non-toxic "aluminosilicate" [$Al_4Si_4O_{10}(OH)_8$] clay particle and micronutrients B as Boric Acid (H_3BO_3), Mn as Manganese Sulphate ($MnSO_4$), Se as Sodium Selenate at different moisture level on growth, yield and quality of tomato in Bangladesh. Some of the data have been presented and expressed in table(s) and others in figures for case of discussion, comparison and understanding. The analysis of variance of data respect of all the parameters has been shown in appendix. The results of each parameter have been discussed and possible interpretations where ever necessary have been given under following headings.

4.1 Plant height

The plant height is one of the most important factors which affect the growth and yield of summer tomato. It depends on several factors like genetic makeup, nutrient availability, moisture level of soil and application of plant growth regulators (PGR), climate etc. Among those nutrient availability and moisture levels are one of the most important factors for desirable plant height.

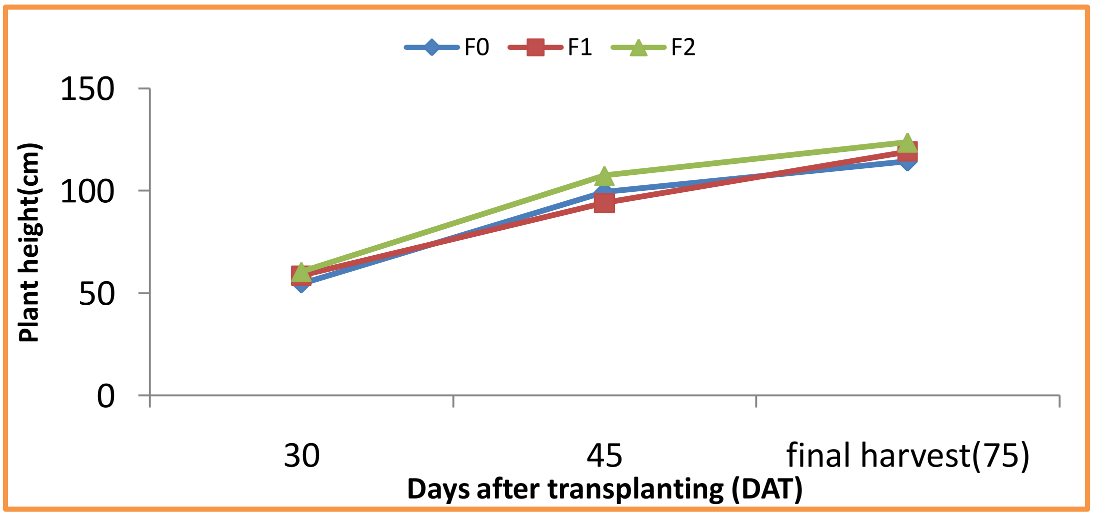
The trend of the plant height at different days after transplanting (DAT) has been shown (Appendix II). A marked variation in plant height was observed at different moisture levels 100% ET (I_0), 80% ET (I_1) & 60% ET (I_2) treatments and statistically it was highly significant at 30, 45 DAT and at the final harvest (Figure 2). The highest plant height (127 cm) was recorded at 80% ET moisture (I_1) treatment whereas the shortest plant height (115.1cm) was recorded at 60% ET moisture (I_2) treatment at final harvest (75 DAT).



[I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]

Figure 2: Effect of moisture levels on plant height (cm)

Plant height was significantly affected by different foliar treatments which have been shown in (Appendix II). Plant height of tomato varied significantly for different treatments which were water (F_0); kaolin 2% & micronutrients 50ppm (F_1); kaolin 4% & micronutrients 100ppm (F_2) at 30, 45 and at final harvest (Figure 3). The tallest plant (123.8 cm) was marked from F_2 treated plants whereas the shortest plant (114.4 cm) was scored from control (F_0) plants at final harvest.



[F_0-control, F_1- Kaolin 2%+ 50ppm micronutrients (B, Zn & Se), F_2-Kaolin4%+100ppm micronutrients (B,Zn & Se)]

Figure 3: Effect of kaolin and micronutrients on plant height (cm)

Significant variation was observed due to the interaction effect of moisture levels and different foliar treatments in terms of plant height (Appendix II). Plant height of tomato observed statistically significant difference among treatments at 30, 45DAT and at final harvest (Table 1). The tallest plant (135.4 cm) was observed from I_1F_2 treatment and smallest plant (110.5cm) was recorded from I_0F_0 treatment which was statistically similar with I_2F_0 treated plant (110.8 cm) at final harvest. The study disclosed that 4%kaolin with 100ppm micronutrient at 80%ET moisture treated plant performed the better result in terms of plant height. It might be due to the synthesis of auxin by the application of micronutrients in tomato plants. Makhan *et al*. (1999-2000) reported that micronutrients may serve as source of energy for synthesis of auxin which helps in elongation of stem.

Table 1: Interaction effect of kaolin and micronutrients on plant height at different moisture levels

Treatment Combinations	Plant height (cm)		
	30DAT	45DAT	Final harvest(75DAT)
I_0F_0	52.33 e	94.75 d	110.5 e
I_0F_1	57.92 cd	105.4 ab	117.6 cd
I_0F_2	58.50 c	106.5 ab	118.0 cd
I_1F_0	59.08 c	106.2 ab	121.8 bc
I_1F_1	61.00 b	75.17 e	123.7 b
I_1F_2	64.00 a	111.7 a	135.4 a
I_2F_0	52.67 e	97.58 cd	110.8 e
I_2F_1	56.67d	101.6 bcd	116.3 d
I_2F_2	59.00 c	104.1 bc	118.1cd
CV%	14.78	11.68	9.90
LSD (0.05)	1.64	7.02	5.33
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly			

[DAT- Days After Transplanting, I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]

[F_0-control, F_1- kaolin 2%+ 50ppm micronutrients (B, Zn & Se), F_2-kaolin4%+100ppm micronutrients (B,Zn & Se)]

4.2 Foliar coverage

Significant variation was observed among various moisture levels I_0, I_1 and I_2 treatments in terms of foliar coverage (Appendix III). Foliar coverage of summer tomato statistically significantly varied among I_0, I_1 and I_2 at 45 days after transplanting (Table 2). The topmost result in terms of foliar coverage (70.65 cm) was recorded from I_1 where as I_2 was scored as the lowest (65.35 cm) at 45DAT.

At 45DAT, statistically significant variation was observed among the foliar treatments in terms of foliar coverage (Appendix III). Foliar coverage of tomato exposed statistically significant variation among the treatments water (F_0), kaolin 2% & micronutrients 50ppm (F_1); kaolin 4% & micronutrients 100ppm(F_2) at 45 DAT(Table 3). The maximum foliar coverage (69.31cm) was marked from kaolin 4% & micronutrients 100ppm (F_2) treated plants whereas the minimum (66.12 cm) was scored from water (F_0) treated plants at 45 DAT (Table 3).

Interaction effect of different moisture levels and foliar treatments in terms of foliar coverage also noted significant variation (Appendix III). The maximum foliar coverage (71.42 cm) at 45 DAT was recorded from I_1F_2 treatment combination, whereas the minimum was (63.25 cm) recorded from I_0F_0 (Table 4).

4.3 Length of internodes

Significant variation was recorded for the length of internodes at various moisture level (Appendix III). Results indicated the longest internodes (6.82 cm) from I_2 whereas the shortest internodes (4.39 cm) were found from I_0 (Table 2).

Length of internodes showed significant variation with the effect of different foliar treatments (Appendix III). Length of internodes was the highest (5.82 cm) from F_2 treatment whereas the lowest (4.88 cm) was observed from F_0 (Table 3).

In case of interaction effect of kaolin and micronutrients at different moisture levels, the length of internodes of tomato plant exposed significant variation (Appendix III). It was remarked by the longest internodes (7.07 cm) from I_1F_2 treatment and the shortest internodes (3.95 cm) from I_0F_0 treatment (Table 4) which was statistically similar with I_2F_0 treatment (4.0 cm).

4.4 Number of leaves per plant

Number of leaves per plant of summer tomato showed significantly significant differences at different moisture regimes at final harvest (Appendix III). The maximum number of leaves per plant (34.47) was recorded from I_1 where as the minimum number (29.97) was recorded from I_0 at 45 DAT (Table 2).

Number of leaves per plant of summer tomato differed significantly due to the effect of different foliar treatments at 45 DAT (Appendix III). F_2 treated plants produced the maximum number of leaves per plant (33.53) while the minimum number of leaves per plant (30.17) was obtained from F_0 treated plants (Table 3).

Different moisture levels and foliar applications of the treatment showed significantly variation due to the interaction effect on number of leaves per plant of summer tomato at 45 DAT (Appendix III). The maximum number of leaves per plant (35.42) was recorded from I_1F_2while the minimum number of leaves per plant (28.33) was recorded from I_0F_0 treated plants (Table 4) which was statistically similar with the treatment I_2F_0 (28.92).

4.5 Length of leaves

Significant variation was recorded for the length of leaves at various moisture levels (Appendix III). Results indicated that longest leaves (36.05 cm) were recorded from I_1 while the shortest leaves (32.61 cm) were recorded from I_0 (Table 2).

The length of leaves showed significant variation with different foliar application of the antitranspirant and growth promoting micronutrients as treatment (Appendix III). The length of leaves was highest (35.17 cm) in F_2 treated plants whereas lowest (32.69 cm) was observed in F_0 treated plants (Table 3).

Significant variation was observed due to the interaction effect of kaolin and micronutrients at different moisture levels in terms of length of leaves of summer tomato (Appendix III). It was remarked that longest leaves (36.75 cm) was found in I_1F_2treated plants whereas the lowest leaves length (31.44 cm) was found in I_0F_0 treated plants (Table 4).

4.6 Number of effective branches per plant

Number of effective branches per plant was exposed significant inequality at different moisture treatments (Appendix III). Maximum number of effective branches per plant (10.19) was observed from I_1whereas the minimum number of effective branches per plant (6.82) was found from I_2 which has notified in (Table 2).

Different foliar treatments significantly influenced the effective branches per plant (Appendix III). F_2 treated plants produced the maximum number of effective branches per plant (9.15) while the minimum number of effective branches per plant (7.20) was obtained from F_0. (Table 3).

Interaction effect of moisture levels and different foliar application of the treatments showed statistically significant differences in terms of number of effective branches per plant (Appendix III). Maximum number of effective branches per plant (11.05) was recorded from I_1F_2 while the minimum number of effective branches per plant (6.02) was recorded from I_0F_0treatment combination (Table 4) which is statistically similar with the I_2F_0treatment (6.20).

Table 2: Effect of moisture levels on plant growth parameters

Treatments	Foliar coverage (cm)	Length of internodes (cm)	Number of leaves per plant	Leaf length (cm)	Number of effective branch per plant
I_0	65.35 b	4.39 b	29.97 b	32.61 b	6.82 b
I_1	70.65 a	6.82 a	34.47 a	36.05 a	10.19 a
I_2	67.39 ab	4.69 b	30.33 ab	33.18 ab	7.439 ab
CV%	8.41	9.79	7.96	13.05	6.50
LSD (0.05)	4.57	0.51	3.27	3.23	3.02
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.					

[I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]

Table 3: Effect of kaolin and micronutrients on plant growth parameters

Treatments	Foliar coverage (cm)	Length of internodes (cm)	Number of leaves per plant	Leaf length (cm)	Number of effective branch per plant
F_0	66.12 b	4.88 b	30.17 b	32.69 b	7.203 b
F_1	67.96 ab	5.20 b	31.08 ab	33.98 ab	8.10 ab
F_2	69.31 a	5.82 a	33.53 a	35.17 a	9.15 a
CV%	8.41	9.79	7.96	13.05	6.50
LSD (0.05)	2.72	0.49	3.07	2.06	1.61
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.					

[F_0-control, F_1- kaolin 2%+ 50ppm micronutrients (B, Zn & Se), F_2-kaolin4%+100ppm micronutrients (B,Zn & Se)

Table 4: Interaction effect of kaolin and micronutrients on plant growth parameters at different moisture levels

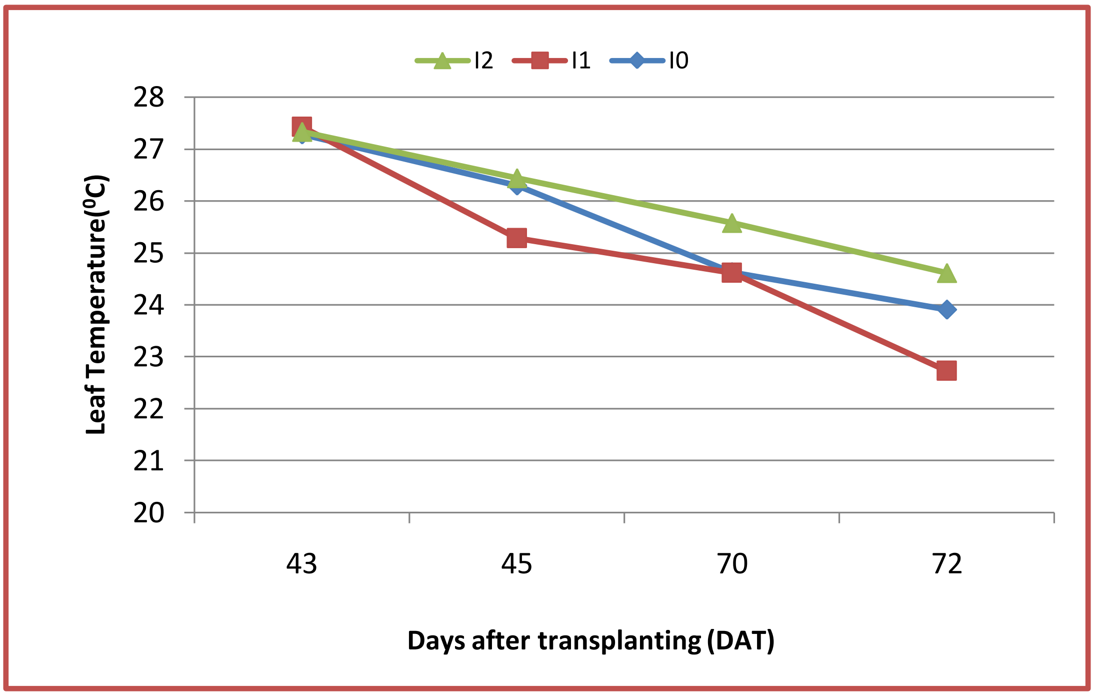
Treatment Combination	Foliar coverage (cm)	Length of internode (cm)	Number of leaves per plant	Length of leaves (cm)	Number of effective branch
I_0F_0	63.25 e	3.950 d	28.33 c	31.44 f	6.017 g
I_0F_1	65.72 d	4.167 d	29.25 c	32.26 e	6.833 f
I_0F_2	67.08 c	5.053bc	32.33 b	34.13 cd	7.617e
I_1F_0	69.44b	6.687 a	33.25b	35.10 b	9.393 c
I_1F_1	71.08 a	6.717 a	34.75 a	36.29a	10.13b
I_1F_2	71.42 a	7.067 a	35.42 a	36.75a	11.05 a
I_2F_0	65.67 d	4.000 d	28.92 c	31.54 ef	6.200 g
I_2F_1	67.08 c	4.723 c	29.25 c	33.38 d	7.333 e
I_2F_2	69.42b	5.350 b	32.83 b	34.63 bc	8.783 d
CV%	8.41	9.79	7.96	13.05	6.50
LSD (0.05)	1.08	0.46	1.37	0.78	0.48
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.					

[I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]

[F_0-control, F_1- kaolin 2%+ 50ppm micronutrients (B, Zn & Se), F_2-kaolin4%+100ppm micronutrients (B,Zn & Se)]

4.7 Leaf temperature

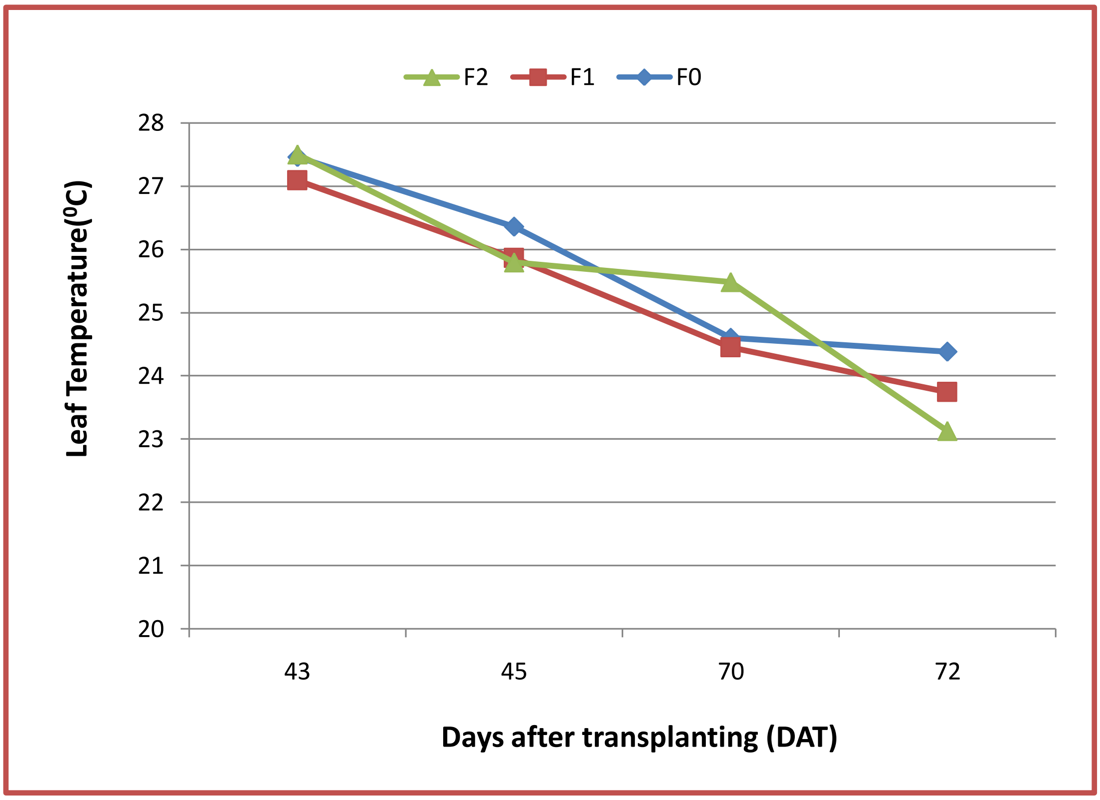
Leaf temperature of summer tomato was influenced significantly at different moisture levels (Appendix IV). The maximum leaf temperature (24.62^{0}C) was recorded from I_2, whereas the minimum leaf temperature (22.73^{0}C) was obtained from I_1 condition (Figure 4).



[I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]

Figure 4: Effect of moisture levels on leaf temperature (^{0}C)

Leaf temperature of summer tomato varied significantly with the application of different foliar treatments (Appendix IV). The maximum leaf temperature (24.38 ^{0}C) recorded from F_0 while F_2 treated plant was exhibited the minimum leaf temperature (23.13^{0}C) (Table 5). Yuly *et al.* (2011) reported that kaolin reduced leaf temperature by 2.5^{0}C approximately at mid day compared to plants non-sprayed with kaolin in rose cut flower which was similar to Mofta and Al-humaid (2002) agreement.



[F_0-control, F_1- kaolin 2%+ 50ppm micronutrients(B, Zn & Se), F_2-kaolin4%+100ppm micronutrients(B, Zn & Se)]

Figure 5: Effect of kaolin and micronutrients on leaf temperature (^{0}C)

Interaction effect of Kaolin and moisture varied significantly on the leaf temperature of summer tomato (Appendix IV). The maximum leaf temperature (25.97^{0}C) was found from I_2F_0 whereas the minimum temperature (22.60^{0}C) recorded from I_1F_2 which was statistically similar to I_0F_2 (22.96^{0}C) (Table 5). These results revealed that foliar applications of kaolin could be considered a useful tool for summer tomato production to reduce leaf temperature at optimum moisture levels (80%ET moisture).

Table 5: Interaction effect of kaolin and micronutrients on leaf temperature (^{0}C) at different moisture levels

Treatment Combinations	Leaf temperature (^{0}C) before foliar spray (43 DAT)	Leaf temperature (^{0}C) after foliar spray (45 DAT)	Leaf temperature (^{0}C) before foliar spray (70 DAT)	Leaf temperature (^{0}C) after foliar spray (72 DAT)
I_0F_0	28.00 b	27.00 a	24.98 ab	24.58 b
I_0F_1	27.30 d	26.15 c	25.05 ab	24.23 b
I_0F_2	26.71 e	26.20 c	26.70 a	22.96 c
I_1F_0	26.70 e	25.59 d	23.79 b	22.78 c
I_1F_1	27.30 d	25.29 e	24.10 b	22.80 c
I_1F_2	28.28 a	24.98 f	25.97 a	22.60 c
I_2F_0	27.68 c	26.50 b	25.02 ab	25.97 a
I_2F_1	26.67 e	26.21 c	25.11 ab	24.18 b
I_2F_2	27.50 cd	26.18 c	23.77 b	23.65 bc
CV%	3.49	4.46	5.25	5.06
LSD (0.05)	0.21	0.27	1.81	1.21
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly				

[DAT- Days After Transplanting, I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]

[F_0-control, F_1- kaolin 2%+ 50ppm micronutrients (B, Zn & Se), F_2-kaolin4%+100ppm micronutrients (B,Zn & Se)]

4.8 Canopy temperature

Canopy temperature of summer tomato was influenced significantly at different moisture levels (Appendix V). The maximum canopy temperature (28.73^{0}C) was recorded from I_2, whereas the minimum temperature (26.51^{0}C) was obtained from I_1 condition (Table 6) at 72 DAT.

Table 6: Effect of moisture levels on canopy temperature (^{0}C)

Treatments	Canopy temperature (^{0}C) before foliar spray (43 DAT)	Canopy temperature (^{0}C) after foliar spray (45 DAT)	Canopy temperature (^{0}C) before foliar spray (70 DAT)	Canopy temperature (^{0}C) after foliar spray (72 DAT)
I_0	29.00 b	28.72 a	29.77 a	28.61 a
I_1	30.61 a	27.55 b	28.49 b	26.51 b
I_2	31.03 a	28.88 a	30.04 a	28.73 a
CV%	4.46	5.11	4.54	6.61
LSD (0.05)	0.43	0.59	0.44	0.38
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly				

[DAT- Days After Transplanting, I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]

Canopy temperature of summer tomato varied significantly with the application of different foliar treatments (Appendix V). The maximum canopy temperature (29.15 ^{0}C) recorded from F_0 while F_2 treated plant was exhibited the minimum leaf temperature (27.04^{0}C) (Table 7).

Table 7: Effect of kaolin and micronutrients on canopy temperature (^0C)

Treatments	Canopy temperature (^0C) before foliar spray (43 DAT)	Canopy temperature (^0C) after foliar spray (45 DAT)	Canopy temperature (^0C) before foliar spray (70 DAT)	Canopy temperature (^0C) after foliar spray (72 DAT)
F_0	30.30 ab	28.88 a	29.94 a	29.15 a
F_1	30.00 b	28.35 ab	29.38 b	27.66 b
F_2	30.34 a	27.92 b	28.98 b	27.04 c
CV%	4.46	5.11	4.54	6.61
LSD (0.05)	0.31	0.57	0.43	0.38
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly				

[F_0-control;F_1-kaolin2%+50ppm micronutrients(B,Zn&Se), F_2-kaolin4%+100ppm micronutrients (B, Zn & Se)]

Interaction effect of kaolin and moisture varied significantly on the surrounding canopy temperature of summer tomato (Appendix V). The maximum canopy temperature (30.47^{0}C) was found from I_2F_0 which was statistically similar with the treatment I_0F_0 (29.93 ^{0}C) whereas the minimum temperature (25.98^{0}C) recorded from I_1F_2 (Table 8). These results revealed that foliar applications of kaolin could be considered a useful tool for summer tomato production to reduce canopy temperature at optimum moisture levels (80%ET moisture) to increase the production level.

Table 8: Interaction effect of kaolin and micronutrients on canopy temperature (^{0}C) at different moisture levels

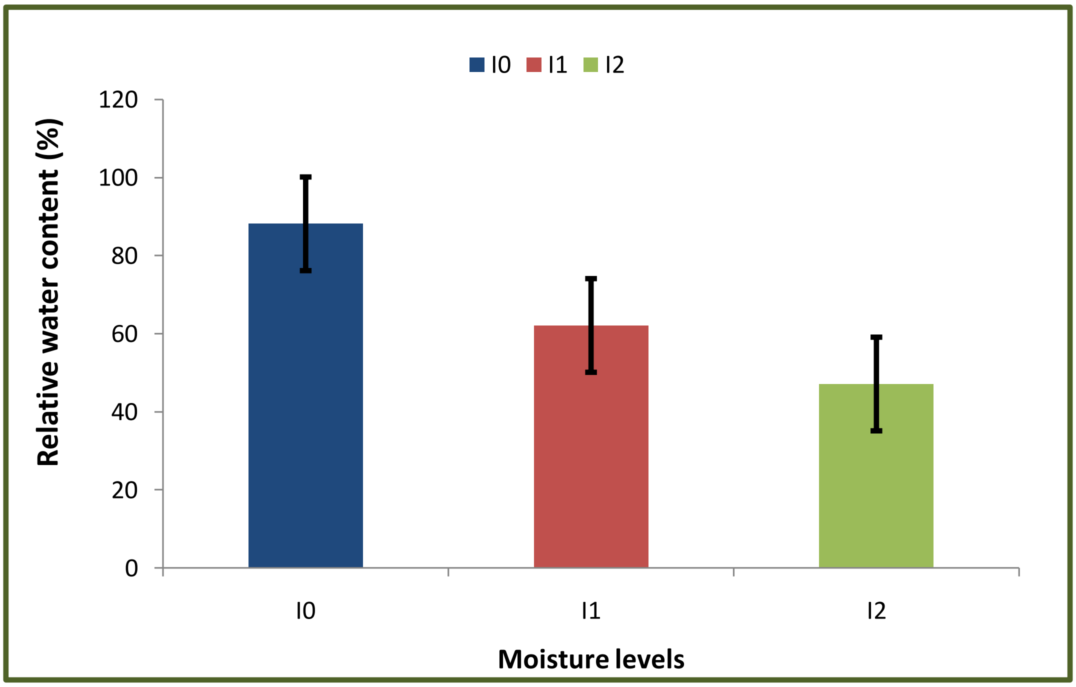
Treatments	Canopy temperature (^{0}C) before foliar spray (43 DAT)	Canopy temperature (^{0}C) after foliar spray (45 DAT)	Canopy temperature (^{0}C) before foliar spray (70 DAT)	Canopy temperature (^{0}C) after foliar spray (72 DAT)
I_0F_0	29.50 c	29.50 a	30.53 a	29.93 a
I_0F_1	28.50 d	28.90 b	30.00 c	28.27 b
I_0F_2	29.00 cd	28.25 d	29.60 d	27.10 c
I_1F_0	30.66 b	28.15 d	29.00 f	27.06 c
I_1F_1	30.50 b	27.50 e	28.47 g	26.50 d
I_1F_2	30.67 b	27.00 f	28.00 h	25.98 d
I_2F_0	30.75 b	29.00 b	30.30 b	30.47 a
I_2F_1	31.00 ab	28.65 bc	29.67 d	28.22 b
I_2F_2	31.33 a	28.50 cd	29.33 e	28.03 b
CV%	4.46	5.11	4.54	6.61
LSD (0.05)	0.55	0.35	0.13	0.55
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.				

[DAT- Days After Transplanting, I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]

[F_0-control, F_1- kaolin 2%+ 50ppm micronutrients (B, Zn & Se), F_2-kaolin4%+100ppm micronutrients (B,Zn & Se)]

4.9 Relative water content

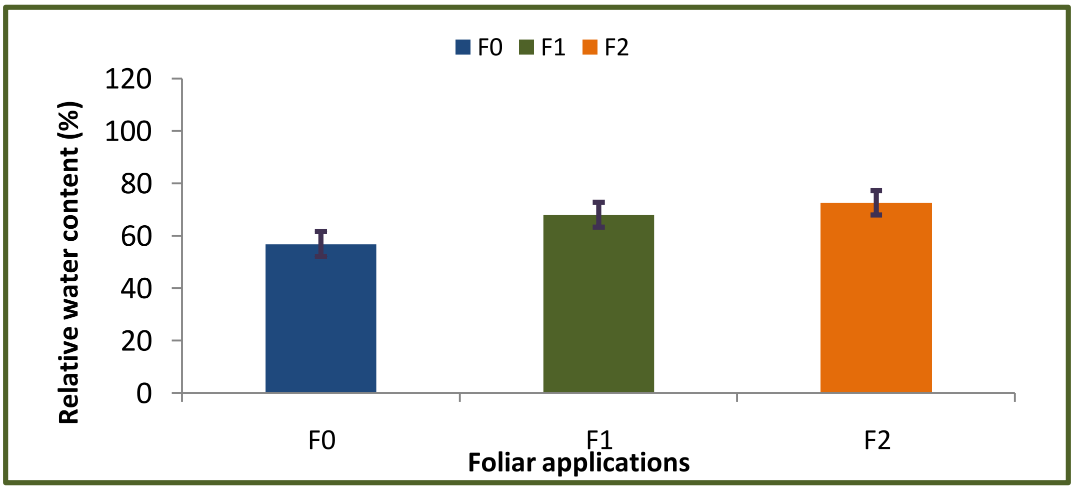
Significant influence was found for different levels of moisture on relative water content (%) tomato (Figure 6) and Appendix VI). Results showed that the highest relative water content (88.19%) was found from I_0 (100% ET moisture) which was significantly different from other treatments where the lowest relative water content (47.11%) was achieved from I_2 (60% ET moisture) followed by I_1 (80% ET moisture).



[I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]

Figure 6: Effect of moisture levels on leaf relative water content (%)

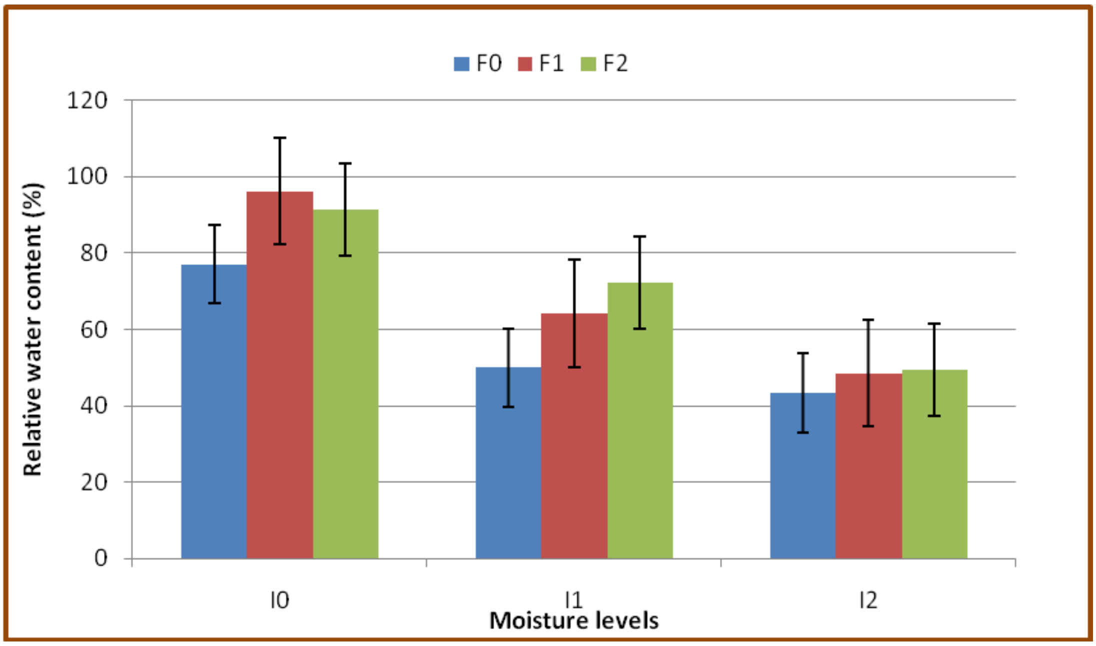
Different levels of kaolin and micronutrients had significant effect on relative water content of tomato leaves (Figure 7) and Appendix VI). Results showed that the highest relative water content (72.63%) was found from F_2 (Foliar spray with 4% kaolin+100ppm micronutrient) where the lowest relative water content (56.80%) was in F_0 (Foliar spray with water only).



[F_0-control, F_1- Kaolin 2%+ 50ppm micronutrients(B, Zn & Se), F_2-Kaolin4%+100ppm micronutrients(B,Zn & Se)]

Figure 7: Effect of kaolin and micronutrients on leaf relative water content (%)

Relative water content of tomato was significantly varied due to the interaction effect of moisture and different foliar treatment (Figure 8) and Appendix VI). Results signified that the maximum relative water content (96.26%) was found from I_0F_2 followed by I_1F_2. Again, the lowest relative water content (43.38%) was found from I_2F_0.



[I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]

[F_0-control, F_1- kaolin 2%+ 50ppm micronutrients(B, Zn & Se), F_2-kaolin4%+100ppm micronutrients(B,Zn & Se)]

Figure 8: Interaction effect of kaolin and micronutrients on leaf relative water content (%) at different moisture levels

4.10 Number of fruits cluster per plant

The number of fruits cluster per plant varied significantly at different levels of moisture (Appendix VI). The maximum number of fruits cluster per plant (3.60) was observed from I_1 whereas the minimum number of fruits cluster per plant (3.08) was recorded from I_0 which has notified in Table 9.

Different treatments of foliar applications significantly influenced the number of fruits cluster per plant (Appendix VI). F_2 treated plants showed the maximum number of fruits cluster per plant (3.54), while the minimum number of fruits cluster per plant (3.07) was obtained from F_0 treated plant (Table 10).

The interaction effect of foliar application of different treatments at different moisture levels showed statistically significant variation in terms of number of fruits cluster per plant (Appendix VI). The maximum number of fruits cluster per plant (4.00) was recorded from I_1F_2, while the minimum number per plant (2.92) was recorded from I_0F_0 treated plants (Table 11)

4.11 Number of total fruits set per plant

Number of fruits set per plant showed significant variation at different moisture levels (Appendix VI). The higher number of fruits set per plant (52.72) was obtained from $I_{1,}$ while the lower number of fruits set per plant (39.62) was obtained from I_0 (Table 9)

Different treatments of foliar application significantly influenced the fruits set per plant (Appendix VI). The maximum number of fruits set per plant (48.95) was recorded from F_2 treated plants, while the minimum number of fruits set per plant (39.75) was obtained from F_0 i.e. controlled condition (Table 10). Results of the study showed that under high temperature, the combination of kaolin and micronutrients (B, Mn & Se) induced higher number of fruit set to some extent. High temperature decreases the levels of auxin and gibberellin's like substances, especially in floral buds and developing fruits of tomato.

Therefore, shortage of auxin and gibberellins could cause the reduction of fruit set under high temperature. It was assumed that the combined treatment of kaolin and micronutrients reduced the affect of high temperature (Sasaki *et al.*, 2005) where kaolin acts as an antitranspirant. Sivaiah *et al*. (2013) also reported that combine application of micronutrients produced the maximum fruit set and fruit yield. Thus, application of kaolin under high temperature would have a positive role in fruit set of summer tomatoes and might be combined effects with micro nutrients..

Interaction effect of kaolin and micronutrients at various moisture regimes of the treatments showed statistically significant variation in terms of number of fruits set per plant (Appendix VI). The maximum number of fruits set per plant (64.68) was recorded from I_1F_2, while the minimum number of fruits set per plant (36.27) was recorded from I_2F_0treated plants (Table 11).

4.12 Fruit length

Average fruit length at the time of harvest was observed as significantly different by the different treatment of moisture (Table 9 and Appendix VII). Results showed that the highest fruit length (48.96 mm) was found from I_1 (80% ET moisture) where the lowest average fruit length (37.31 mm) was achieved from I_0 (100% ET moisture). Similar result was also found by Pugalia *et al.,* (1992).

Different levels of kaolin and micronutrients had significant effect on fruit length of tomato (Table 10 and Appendix VII). Results indicated that the highest fruit length (46.44 mm) was found from F_2 (Foliar spray with 4% Kaolin and 100 ppm micronutrients) where the lowest fruit length (37.53 mm) was from F_0 (control). The result found by Singh *et al.,* (2002) was similar with the present study.

Fruit length of tomato was significantly influenced by interaction effect of kaolin and micronutrients at various level of moisture (Table 11 and Appendix VII). Results revealed that the maximum fruit length (52.83mm) was found from I_1F_2 Again, the lowest fruit length (32.27mm) was found from I_0F_0 which was statistically similar with I_2F_0 (34.24mm)

4.13 Fruit diameter

Significantly influence was found for average fruit diameter at the time of harvest by the different levels of moisture (Table 9 and Appendix VI). Results signified that the highest fruit diameter (47.78 mm) was found from I_1 (80% ET moisture) which was statistically different from other treatment where the lowest average fruit diameter (36.53 mm) was achieved from I_0. Intermediate level of fruit diameter was obtained from I_1 (60% ET moisture).

Different levels of foliar treatment with kaolin and micronutrients had significant effect on fruit diameter of tomato (Table 10 and Appendix VI). Results indicated that the highest fruit diameter (45.50 mm) was found from F_2 treatment where the lowest fruit diameter (36.76 mm) was achieved from F_0 (Foliar spray of water; control). The result found by Singh *et al.*, (2002) was similar with the present study.

Fruit diameter of tomato was significantly influenced by interaction effect of kaolin with micronutrient (Table 11 and Appendix 11) at different moisture levels. Results revealed that the maximum fruit diameter (51.63 mm) was found from I_1F_2. Again, the lowest fruit diameter (31.31 mm) was found from I_0F_0.

4.14 Fruit firmness

Firmness of summer tomato was influenced significantly at different moisture level (Appendix VII). The maximum firmness of tomato (6.31 Neuton) was recorded from I_1, while the minimum (5.52 Neuton) obtained from I_0 i.e. 100% ET moisture level (Table 9).

Firmness of summer tomato varied significantly with the foliar application of different treatments of growth and yield promoting elements (Appendix VII). The maximum firmness (6.30 Neuton) of summer tomato recorded from F_2 treated plants while the minimum firmness (5.58 Neuton) obtained from F_0 (Table 10).

Interaction effect of the kaolin and differrent treatments of foliar application at different level of moisture varied significantly on the firmness of summer tomato (Appendix VII). The maximum firmness of summer tomato (6.74 Neuton) was found from I_1F_2 whereas the minimum firmness (5.13Neuton) recorded from I_0F_0 (Table 11). Therefore, foliar application of 4%kaolin and 100ppm micronutrients at 80%ET moisture level made tomato fruits harder which may increase the storage period of tomato.

Table 9: Effect of moisture levels on yield contributing parameters

Treatments	Number of fruit cluster per plant	Total Fruit per plant	Fruit diameter (mm)	Fruit length (mm)	Fruit firmness (Neuton)
I_0	3.08 b	39.62 b	36.53 b	37.31 b	5.52 b
I_1	3.60 a	52.72 a	47.78 a	48.96 a	6.31 a
I_2	3.21 ab	40.94 b	39.95 ab	40.09 ab	5.77 ab
CV%	9.89	4.03	8.51	9.67	10.69
LSD (0.05)	0.442	10.13	9.87	10.44	0.68
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly					

[DAT- Days After Transplanting, I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]

Table 10: Effect of kaolin and micronutrients on yield contributing parameters

Treatments	Number of fruit cluster per plant	Total Fruit per plant	Fruit diameter (mm)	Fruit length (mm)	Fruit firmness (Neuton)
F_0	3.08 b	39.75 b	36.76 b	37.53 b	5.58 b
F_1	3.60 a	44.57 ab	42.00 ab	42.39 ab	5.71 ab
F_2	3.21 ab	48.95 a	45.50 a	46.44 a	6.30 a
CV%	9.89	4.03	8.51	9.67	10.69
LSD (0.05)	0.442	7.88	7.53	7.65	0.65
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly					

[F_0-control, F_1- kaolin 2%+ 50ppm micronutrients (B, Zn & Se), F_2-kaolin4%+100ppm micronutrients (B,Zn & Se)]

Table 11: Interaction effect of kaolin and micronutrients on yield contributing parameters at different moisture levels

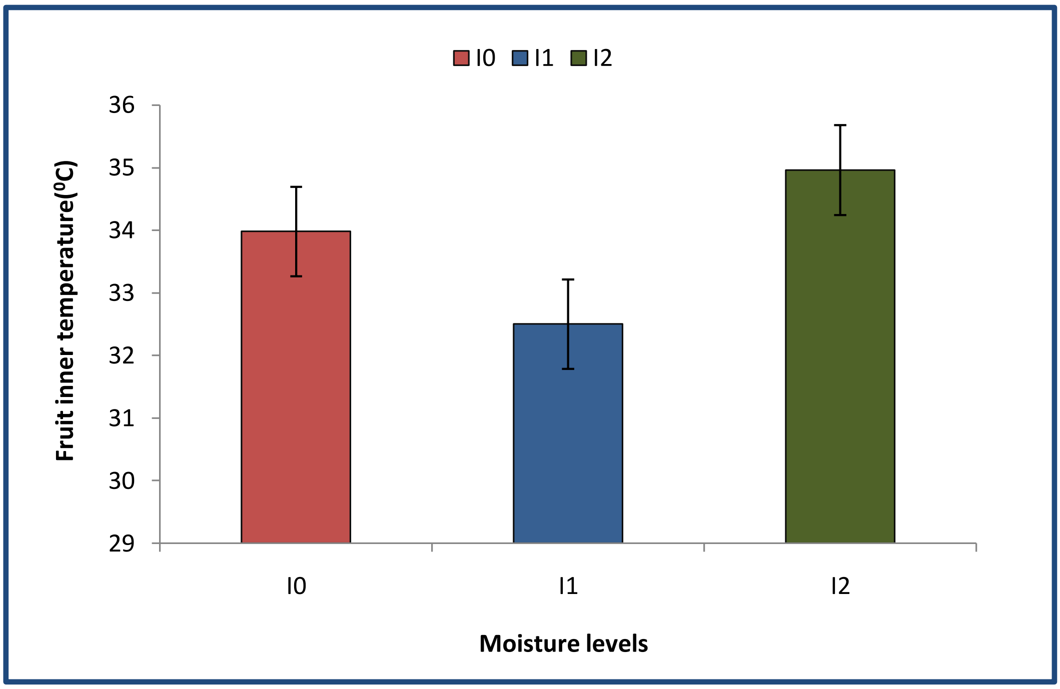
Treatment combination	Number of fruit cluster per plant	Total Fruit per plant	Fruit diameter (mm)	Fruit length (mm)	Fruit firmness (Neuton)
I_0F_0	2.92 e	41.06 bc	31.31 g	32.27 f	5.13 g
I_0F_1	3.14 de	41.06 bc	37.80 e	38.17 e	5.55 ef
I_0F_2	3.20 cd	36.75 c	40.49 d	41.50 d	5.87 de
I_1F_0	3.22 cd	41.93 bc	44.74 bc	46.07 bc	6.22 bc
I_1F_1	3.583 b	51.53 b	46.96 b	47.99 b	5.96 cd
I_1F_2	4.000 a	64.68 a	51.63 a	52.83 a	6.74 a
I_2F_0	3.06 de	36.27 c	34.24 f	34.26 f	5.40 fg
I_2F_1	3.17 d	41.13 bc	41.24 d	41.00 d	5.63 ef
I_2F_2	3.417 bc	45.42 bc	44.38 c	45.00 c	6.300 b
CV%	9.89	4.03	8.51	9.67	10.69
LSD (0.05)	0.342	11.63	2.30	2.34	0.33
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly					

[DAT- Days After Transplanting, I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]

[F_0-control, F_1- kaolin 2%+ 50ppm micronutrients (B, Zn & Se), F_2-kaolin4%+100ppm micronutrients (B,Zn & Se)]

4.15 Inner fruits temperature

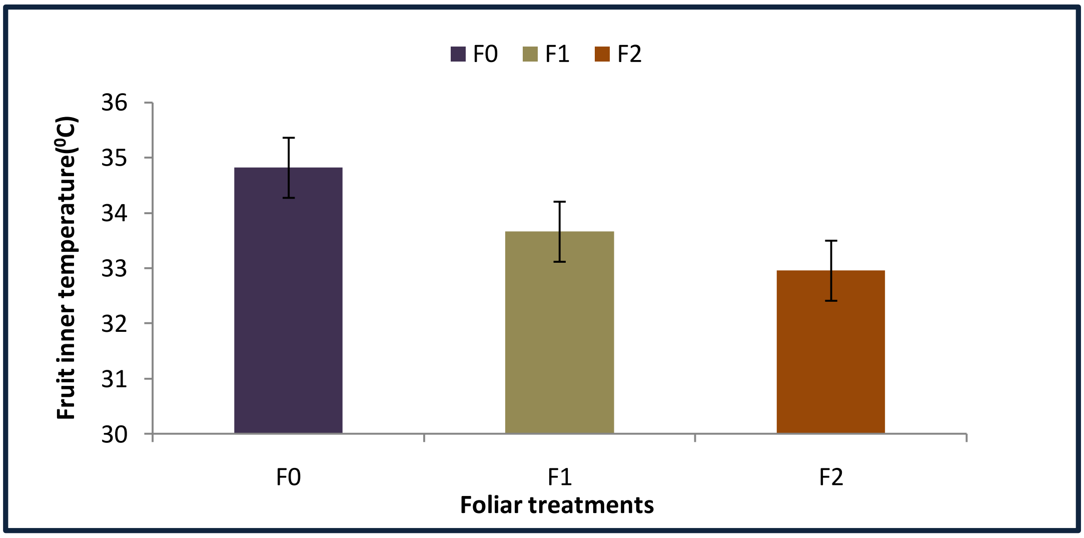
Inner fruits temperature of tomato was influenced significantly with the effect of moisture (Appendix VII). The highest fruits inner temperature was recorded (34.96^{0}C) from I_2 condition, whereas the lowest fruit inner temperature (32.50) was obtained from I_1 condition (Figure 9).



[I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]

Figure 9: Effect of moisture levels on fruit inner temperature (^{0}C)

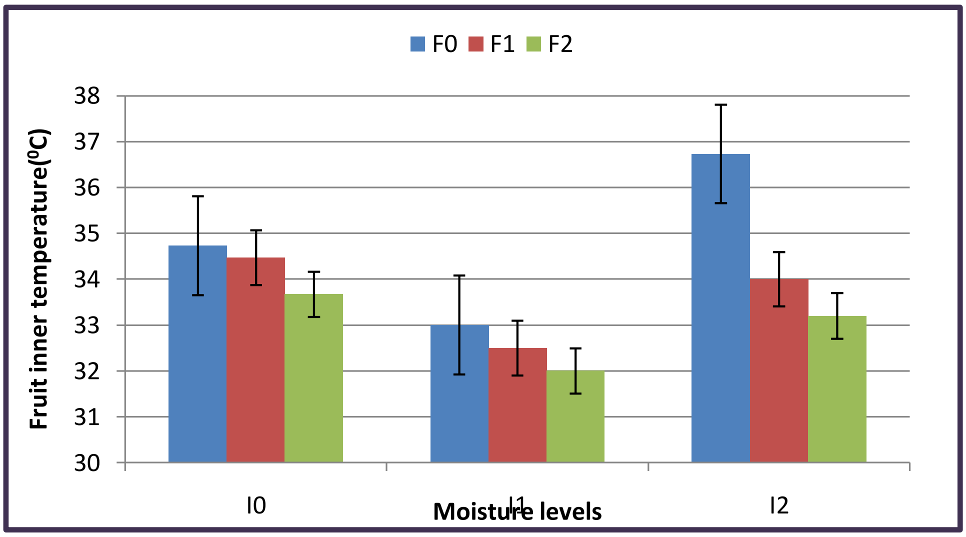
Inner fruits temperature of tomato varied significantly with the foliar application of kaolin and micronutrients (Appendix VII). The maximum inner temperature of fruits (34.82^{0}C) recorded from F_0 treated plant while the minimum fruit inner temperature (32.96^{0}C) was found from F_2 treated plants (Figure 10). The result of the present study is agreed with the result of Cantore *et.al.* (2008). They have concluded that inner fruit temperature of kaolin treated plant was 4.4℃ lower than the control. The same result also revealed by Mofta and Al-humaid (2002).



[F_0-control, F_1- kaolin 2%+ 50ppm micronutrients (B, Zn & Se), F_2-kaolin4%+100ppm micronutrients (B,Zn & Se)]

Figure 10: Effect of kaolin and micronutrients on fruit inner temperature (^{0}C)

Combination of kaolin and micronutrients at different levels of moisture varied significantly on fruits inner temperature of tomato (Appendix VII). The maximum inner temperature of fruits (36.73^{0}C) was found from I_2F_0, whereas the minimum (32.00^{0}C) recorded from I_1F_2 (Figure11).



[I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]

[F_0-control, F_1- Kaolin 2%+ 50ppm micronutrients (B, Zn & Se), F_2-Kaolin4%+100ppm micronutrients (B,Zn & Se)]

Figure 11: Interaction effect of kaolin and micronutrients on fruit inner temperature (^{0}C) at different moisture levels

4.16 Chlorophyll content

Chlorophyll content of summer tomato was influenced significantly at different moisture levels (Appendix VII). I_1 scored the maximum chlorophyll content percentage (45.67%), whereas the minimum chlorophyll content (39.11%) was obtained from I_2 (Table 12).

Chlorophyll content of summer tomato varied significantly with the foliar application of different treatments (Appendix VII). The maximum chlorophyll content percentage (45.45%) recorded from F_2 treated plants, while the minimum chlorophyll content (36.35 %) was found from F_0 treated plants (Table 13).

Interaction effect of polythene shed and differrent foliar application of treatments varied significantly on chlorophyll content of summer tomato (Appendix VII). The maximum chlorophyll content percentage (48.89%) obtained from I_1F_2, while the minimum (26.96%) recorded from I_2F_0 treatment (Table 14).

4.17 Tomato P^H

For the effect of moisture, it was observed from the results of the present experiment that the moisture levels in plant significantly varied P^H of the extract of summer tomato (Table 12) and (Appendix VIII). Highest fruit P^H was obtained from I_1 treatment (3.70), whereas the lowest fruit P^H was from I_2 treatment (3.57)

Different foliar applications of the treatment significantly affect the P^H of summer tomato (Table 13) and (Appendix VIII). Maximum P^H value (3.67) was obtained from F_2 treatment, whereas the minimum (3.61) was in F_0 treatment.

Interaction effect of kaolin and and differrent foliar treatments at 80%ET moisture level significantly varied the P^H of summer tomato (Table 14) and (Appendix VIII). The maximum (3.79) was obtained from I_1F_2 treatment while the minimum (3.52) P^H was in I_2F_0 treatment.

4.18 Content of vitamin-C

This research work exhibited distinct variations in terms of content of vitamin-C of summer tomato which has greatly affected with moisture level (Appendix VIII). The maximum Vitamin-C content (12.96 mg per 100 g of tomato) was found from I_1, while the minimum content of Vitamin-C (9.38) was obtained from I_0 (Table 12).

Vitamin-C content in summer tomato varied significantly with the foliar application of Kaolin and micronutrients (Appendix VIII). The maximum vitamin-C content (13.35) was obtained from F_2 treated tomato plants, whereas the minimum content of Vitamin-C (9.00) was recorded from controlled condition of water treated plants (F_0) (Table 13).

Interaction effect of the foliar application at different moisture level varied significantly for the content of vitamin-C of summer tomato (Appendix VIII). The maximum amount of vitamin-C content (14.29) was obtained from I_1F_2 which was statistically similar to I_2F_2 (13.92), I_0F_2 (14.19) while the minimum amount of vitamin-C content (7.44) was recorded from I_0F_1 (Table 14). Therefore, antitranspirant kaolin and foliar application of yield contributing elements at 80%ET level of moisture produced better quality of tomato in terms of vitamin-C which could improve health status of the consumers.

4.19 Total soluble solids (TSS)

This research work exhibited distinct variations in total soluble solids (TSS) of summer tomato at different moisture levels (Appendix VIII). The maximum TSS in summer tomato (4.81 %) was found from I_1, while the minimum was (3.64 %) obtained from I_0 (Table 12).

Total soluble solids (TSS) in summer tomato varied significantly with the application of different foliar treatments (Appendix VIII). The maximum TSS (4.31%) was found from F_2 treated plants whereas the minimum TSS (3.86%) was found from controlled condition F_0 (Table 13).

Interaction effect of kaolin and micronutrient at different moisture level varied significantly on TSS of summer tomato (Appendix VIII). It was observed that maximum TSS (5.02 %) was obtained from I_1F_2 treated plants, which was statistically similar with I_1F_1 （4.91 %） whereas the minimum (3.52 %) was recorded from I_2F_0 which was statistically identical with I_0F_0 (Table 14).

Table 12: Effect of moisture levels on growth and fruit quality parameters

Treatments	Chlorophyll content of leaves(%)	Fruit P^H	Vitamin-C (mg per 100 g)	Total Soluble Solid(brix%)
I_0	41.01 ab	3.66 a	9.38 c	3.64 b
I_1	45.67 a	3.70 a	12.96 a	4.81 a
I_2	39.11 b	3.57 b	10.46 b	3.79 ab
CV%	10.93	5.40	8.72	4.24
LSD (0.05)	5.77	0.054	0.940	1.09
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly				

[I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]

Table 13: Effect of kaolin and micronutrients on growth and fruit quality parameters

Treatments	Chlorophyll content of leaves (%)	Fruit P^H	Vitamin-C (mg per 100 g)	Total Soluble Solid (brix%)
F_0	36.35 b	3.16 b	9.00 c	3.86 b
F_1	43.98 a	3.64 b	10.44 b	4.06 ab
F_2	45.45 a	3.67 a	13.35 a	4.31 a
CV%	10.93	5.40	8.72	4.24
LSD (0.05)	5.47	0.054	0.938	0.38
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly				

[F_0-control, F_1- kaolin 2%+ 50ppm micronutrients (B, Zn & Se), F_2-kaolin4%+100ppm micronutrients (B,Zn & Se)]

Table 14: Interaction effect of kaolin and micronutrients on growth and fruit quality parameters at different moisture levels

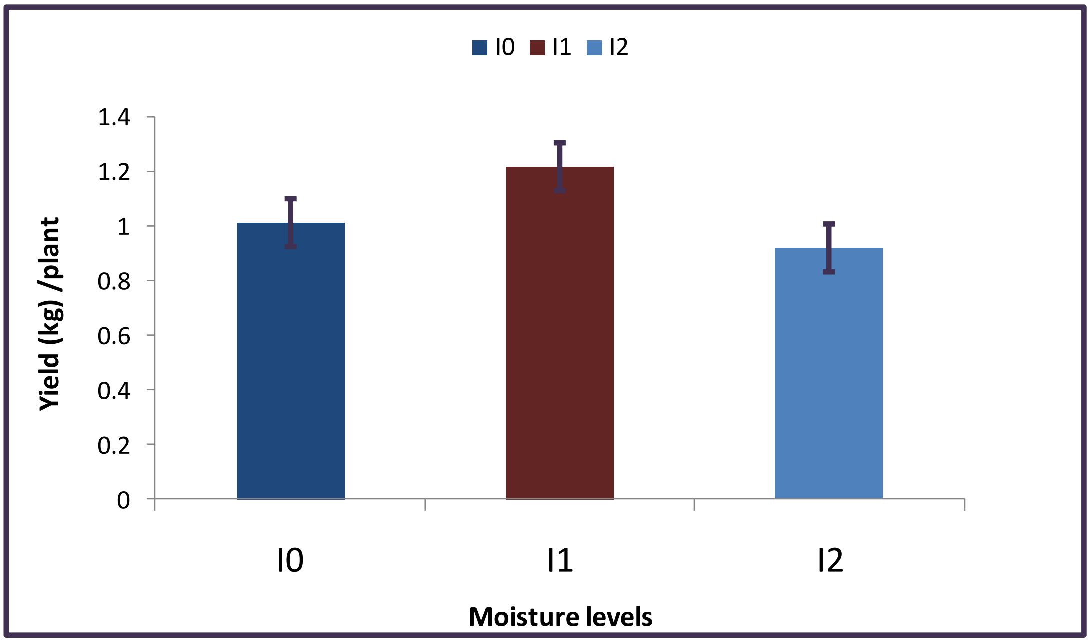
Treatments	Chlorophyll content of leaves (%)	Fruit P^H	Vitamin-C (mg per 100 g)	Total Soluble Solid (brix%)
I_0F_0	37.78 c	3.57 bc	11.56 b	3.52 e
I_0F_1	41.82 bc	3.79 a	7.44 e	3.62 de
I_0F_2	43.42 abc	3.62 b	14.19 a	3.79 d
I_1F_0	44.32 abc	3.66 b	9.13 cd	4.50 b
I_1F_1	43.81 abc	3.64 b	8.89 de	4.91 a
I_1F_2	48.89 a	3.79 a	8.29 de	5.02 a
I_2F_0	26.96 d	3.52 c	14.29 a	3.57 e
I_2F_1	46.32 ab	3.59 bc	10.67 bc	3.66 de
I_2F_2	44.05 abc	3.60 bc	13.92 a	4.13 c
CV%	10.93	5.40	8.72	4.24
LSD (0.05)	5.03	0.093	1.628	0.21
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.				

[DAT- Days After Transplanting, I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]

[F_0-control, F_1- kaolin 2%+ 50ppm micronutrients (B, Zn & Se), F_2-kaolin4%+100ppm micronutrients (B,Zn & Se)]

4.20 Yield (kg) /plant

It was observed from the results of the present experiment that different levels of moisture significantly varied the total fruit yield per plant (Appendix VIII). Total fruit weight of summer tomato per plant was observed the maximum (1.22 kg) from I_1, while the minimum fruit weight per plant (0.92 kg) obtained from I_2 (Figure 12).In I_1 treated plant some fruits were seen with rotten symptom. This might be due to the presence of excess moisture in fruit which results to various fruit diseases performing the lower yield of the plant.

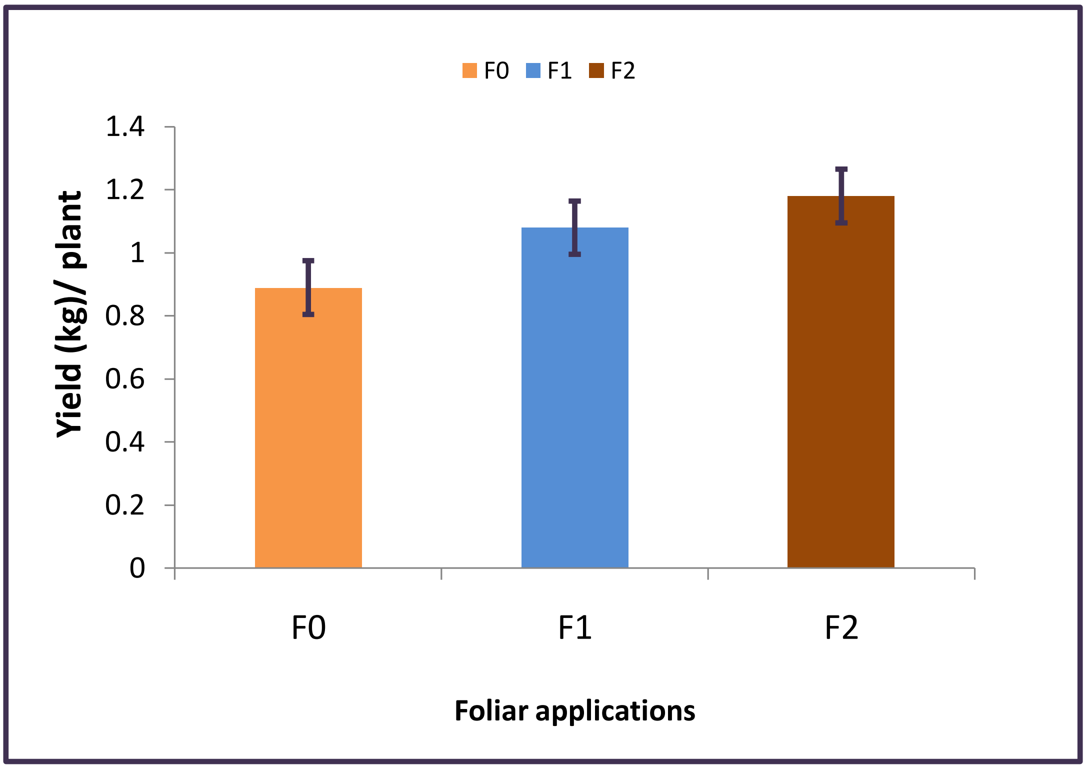


[I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]

Figure 12: Effect of moisture levels on yield (kg) per plant

Total fruit weight varied significantly with the application of different foliar treatments (Appendix VIII). The total fruit weight of summer tomato per plant was observed the maximum (1.18 kg) from F_2 treated plant, while the minimum (0.89 kg) obtained from F_0 treated plants (Figure 13). Baliyan *et al.* (2013) concluded that the use of micronutrients could increase the fruit set, yield and economic benefit of summer tomato production.

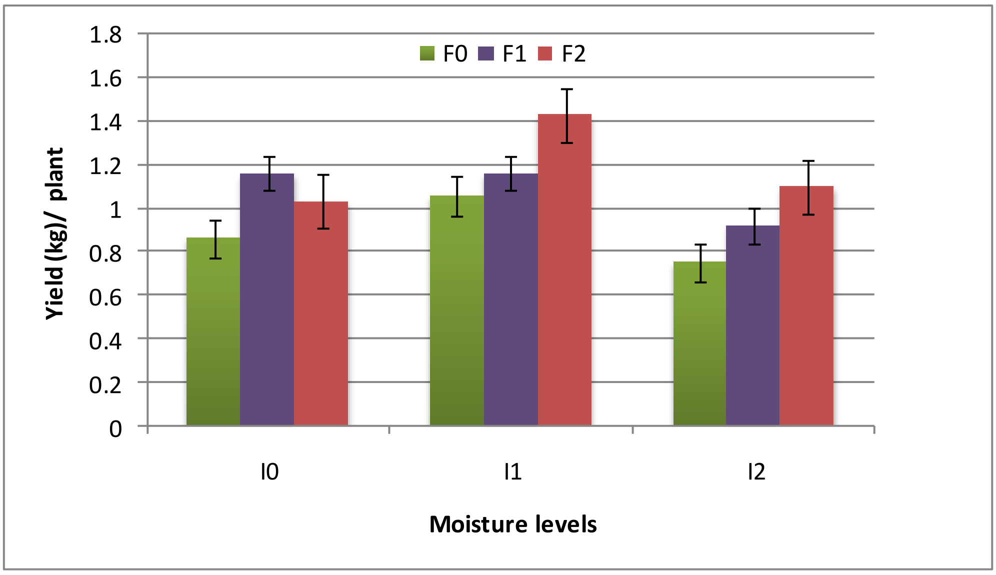
Along with this, kaolin at a time worked as an antitranspirant as well as insect barrier which might be resulted to the increased yield status of plant.



[F_0-control, F_1- kaolin 2%+ 50ppm micronutrients(B, Zn & Se), F_2-kaolin4%+100ppm micronutrients(B, Zn & Se)]

Figure 13: Effect of kaolin and micronutrients on yield (kg) per plant

Interaction effect of kaolin and micronutrients at different moisture levels greatly influenced the total fruit weight per plant (Appendix VIII). The total fruit weight of summer tomato per plant was observed the maximum (1.43kg) from I_1F_2 treated plants, while the minimum fruit weight of tomato per plant (0.75kg) was found under I_2F_0 treatment (Figure 14).



[I_0-100% ET moisture, I_1-80%ET moisture, I_2-60%ET moisture]
[F_0-control, F_1- kaolin 2%+ 50ppm micronutrients(B, Zn & Se), F_2-kaolin4%+100ppm micronutrients(B, Zn & Se)]

Figure 14: Interaction effect of kaolin and micronutrients on yield (kg) per plant at different moisture levels

Therefore, moisture at 80%ET level (I_1) and foliar application of 4%Kaolin and 100ppm micronutrients (B, Mn, Se) (F_2) was the best combination for the production of summer tomato in term of growth, yield and quality. Hence, moisture at 80%ET moisture level (I_1) in combination with F_2 treatment combination represented a most excellent treatment in terms of yield for the summer tomato production in Bangladesh.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Horticultural Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh to determine the performance of summer tomato BARI hybrid – 4 with the foliar application of kaolin and micronutrients at different moisture levels. The experiment consisted of two factors: **Factor A**: Moisture levels; I_0-100% ET(evapotranpiration) moisture, I_1- 80% ET moisture and I_2-60% ET moisture. And **Factor B**: Foliar application of kaolin and micronutrients where F_0-control (spraying tap water only), F_1- spraying of kaolin as an antitranspirant @2% solution and micronutrients (B, Mn & Se) @50 ppm for each of the nutrient solution. F_2- spraying of Kaolin as an antitranspirant @4% solution and micronutrients (B, Mn & Se) @100 ppm for each of the nutrient solution. There were 9 (3 × 3) treatments combination. The two factorial experiments were laid out in Complete Randomized Design (CRD) with three replications. Data on growth, yield and quality parameters were recorded and significant variation was observed. The results of the experiment have been summarized below:

In case various moisture levels, the highest plant height (127 cm) was recorded with 80% ET moisture (I_1) treatment, whereas the shortest plant height (115.1cm) was recorded at 60% ET moisture (I_2) treatment at 45 days after transplanting. The topmost result in terms of foliar coverage (70.65 cm) was recorded from I_1, whereas I_2 was scored as the lowest (65.35cm) at 45 DAT. The longest internodes (6.82 cm) were found from I_1, whereas the shortest internodes (4.39cm) were found from I_0. The maximum number of effective branches per plant (10.19) was observed from I_1, whereas the minimum number of effective branches per plant (6.82) was found from I_0.

The maximum number of leaves per plant (34.47) was recorded from I_1, whereas the minimum number (29.97) was recorded from I_0 at 45 DAT. The longest leaves (36.05 cm) were recorded from I_1, while the shortest leaves

(32.61 cm) were recorded from I_0. The maximum number of fruits cluster per plant (3.60) was observed from I_1, whereas the minimum number of fruits cluster per plant (3.08) was recorded from I_0. I_1 scored the maximum chlorophyll content percentage (45.67%), whereas the minimum chlorophyll content (39.11%) was obtained from I_2. The maximum leaf temperature (24.62^{0}C) was recorded from I_2, whereas the minimum leaf temperature (22.73^{0}C) was obtained from I_1 condition. The maximum P^H (3.7) was recorded from I_1, whereas the minimum P^H (3.57) was obtained from I_2 condition. The maximum canopy temperature (28.73^{0}C) was recorded from I_2, whereas the minimum canopy temperature (26.51^{0}C) was obtained from I_1 condition. The maximum brix percentage in summer tomato (4.81 %) was found from I_1, while the minimum (3.64 %) obtained from I_0. The highest fruits inner temperature was recorded (34.96^{0}C) from I_2 condition, whereas the lowest fruit inner temperature (32.5^{0}C) was obtained from I_1 condition. The maximum firmness of tomato (6.31 Neuton) was recorded from I_1, while the minimum (5.52 Neuton) was obtained from I_0 i.e. controlled condition. The maximum vitamin-C content (12.96 mg per 100 g of tomato) was found from I_1, while the minimum content of vitamin-C (9.38 mg per 100 g of tomato) was obtained from I_0. The maximum fruit length (48.96 mm) recorded from I_1, while the minimum length (37.31 mm) was obtained from I_0. The maximum fruit diameter (47.78 mm) was recorded from I_1, while the minimum diameter (36.5 mm) was obtained from I_0. The maximum leaf relative water content (88.19 %) was recorded from I_0, while the minimum Relative Water Content (47.11%) was obtained from I_2. The higher number of fruits set per plant (52.72) was obtained from $I_{1,}$ while the lower number of fruits set per plant (39.62) was obtained from $I_{0.}$

Total fruit weight of summer tomato per plant was observed the maximum (1.22 kg) from I_1, while the minimum fruit weight per plant (0.92 kg) obtained from I_2.

In case various foliar application of kaolin and micronutrients, the highest plant height (123.8 cm) was recorded with the spraying of kaolin @ 4% solution and micronutrients (B, Mn & Se) @100ppm for each of the nutrient solution (F_2) treatment, whereas the shortest plant height (114.4cm) was recorded at control condition (F_0) at 45 days after transplanting. The topmost result in terms of foliar coverage (69.31 cm) was recorded from F_2, whereas F_0 scored the lowest (66.12 cm) at 45 DAT. The longest internodes (5.82 cm) were found from F_2, whereas the shortest internodes (4.88 cm) were found from F_0. The maximum number of effective branches per plant (9.15) was observed from F_2, whereas the minimum number of effective branches per plant (7.2) was found from F_0. The maximum number of leaves per plant (33.53) was recorded from F_2, whereas the minimum number (30.17) was recorded from F_0 at 45DAT. The longest leaves (35.17 cm) were recorded from F_2, while the shortest leaves (32.69 cm) were recorded from F_0. The maximum number of fruits cluster per plant (3.54) was observed from F_2 where as the minimum number of fruits cluster per plant (3.07) was recorded from F_0. F_2 scored the maximum chlorophyll content percentage (45.45%), whereas the minimum chlorophyll content (36.35%) was obtained from F_0. The maximum leaf temperature (24.38^{O}C) was recorded from F_0, whereas the minimum leaf temperature (23.13^{O}C) was obtained from F_2 condition. The maximum P^H (3.67) was recorded from F_2, whereas the minimum P^H (3.61) was obtained from F_0 condition. The maximum canopy temperature (29.15^{O}C) was recorded from F_0, whereas the minimum leaf temperature (27.04^{O}C) was obtained from F_2. The maximum brix percentage in summer tomato (4.31 %) was found from F_2, while the minimum (3.86%) obtained from F_0. The highest fruit inner temperature was recorded (34.82^{O}C) from F_0 condition, whereas the lowest fruit inner temperature (32.96^{O}C) was obtained from F_2 condition.

The maximum firmness of tomato (6.30 Neuton) was recorded from F_2, while the minimum (5.58 Neuton) was obtained from F_0 i.e. controlled condition. The maximum Vitamin-C content (13.35 mg per 100 g of tomato) was found from F_2, while the minimum content of Vitamin-C (9.00 mg per 100 g of tomato) was obtained from F_0. The maximum fruit length (46.44mm) recorded from F_2, while the minimum length (37.53 mm) was obtained from F_0. The maximum fruit diameter (45.50 mm) was recorded from F_2, while the minimum diameter (36.76 mm) was obtained from F_0. The maximum leaf relative water content (72.63%) was recorded from F_2, while the minimum leaf relative water content (56.80%) was obtained from F_0. The higher number of fruits set per plant (48.95) was obtained from $F_{2,}$ while the lower number of fruits set per plant (39.75) was obtained from $F_{0.}$ Total fruit weight of summer tomato per plant was observed the maximum (1.18 kg) from F_2, while the minimum fruit weight per plant (0.89 kg) obtained from F_0.

In case of interaction effect of different moisture levels and foliar application of the treatments, the tallest plant (135.4 cm) was observed from I_1F_2 and smallest plant (110.5 cm) was recorded at I_0F_0 treatment at 45 days after transplanting. The maximum foliar coverage (71.42 cm) at 45 DAT was recorded from I_1F_2 treatment combination, whereas the minimum was (63.25 cm) recorded from I_0F_0. It was remarked the longest internodes (7.07 cm) from I_1F_2 treatment and the shortest internodes (3.95 cm) from I_0F_0. The maximum number of effective branches per plant (11.05) was recorded from I_1F_2, while the minimum number of effective branches per plant (6.02) was recorded from I_0F_0 treatment combination. The maximum number of leaves per plant (35.42) was recorded from I_1F_2, whereas the minimum number (28.33) was recorded from I_0F_0 at 45DAT. The longest leaves (36.75cm) were recorded from I_1F_2, while the shortest leaves (31.44cm) were recorded from I_0F_0. The maximum number of fruits cluster per plant (4.00) was observed from I_1F_2 where as the minimum number of fruits cluster per plant (2.92) was recorded from I_0F_0.

I_1F_2 scored the maximum chlorophyll content percentage (48.89%), whereas the minimum chlorophyll content (26.96%) was obtained from I_2F_0. The maximum leaf temperature (25.97^{O}C) was recorded from I_2F_0, whereas the minimum leaf temperature (22.60^{O}C) was obtained from I_1F_2 condition. The maximum P^H (3.80) was recorded from I_1F_2, whereas the minimum P^H (3.52) was obtained from I_2F_0 condition. The maximum canopy temperature (30.47^{O}C) was recorded from I_2F_0, whereas the minimum leaf temperature (25.98^{O}C) was obtained from I_1F_2 treatment combination. The maximum brix percentage in summer tomato (5.02%) was found from I_1F_2, while the minimum (3.52%) obtained from I_0F_0. The highest fruit inner temperature was recorded (36.73^{O}C) from I_2F_0 condition, whereas the lowest fruit inner temperature (32.00^{O}C) was obtained from I_1F_2 condition. The maximum firmness of tomato (6.74 Neuton) was recorded from I_1F_2, while the minimum (5.13 Neuton) was obtained from I_0F_0. The maximum Vitamin-C content (14.29 mg per 100 g of tomato) was found from I_1F_2, while the minimum content of Vitamin-C (7.44 mg per 100 g of tomato) was obtained from I_0F_0. The maximum fruit length (52.83 mm) recorded from I_1F_2, while the minimum length (32.27 mm) was obtained from I_0F_0 treatment combination. The maximum fruit diameter (51.63 mm) was recorded from I_1F_2, while the minimum diameter (31.31 mm) was obtained from I_0F_0. The maximum leaf relative water content (96.26%) was recorded from I_0F_2 was statistically similar with I_0F_1 (91.32%) while the minimum leaf relative water content (43.38%) was obtained from I_2F_0. The higher number of fruits set per plant (64.68) was obtained from I_1F_2 while the lower number of fruits set per plant (36.27) was obtained from I_2F_0. Total fruit weight of summer tomato per plant was observed the maximum

(1.43 kg) from I_1F_2 treatment combination while the minimum fruit weight per plant (0.75 kg) was obtained from I_2F_0 treatment combination.

Conclusion

Considering the findings of the experiment, it may be concluded that:

1. Foliar application of kaolin perform well to reduce different temperature effect on summer tomato (Leaf temperature, canopy temperatue, fruit inner temperature, leaf relative water content) and micronutrients elements provided the maximum yield and quality parameters (Fruit firmness, vitamin – C and TSS).
2. At mild water stress (80% ET moisture) plant growth and fruiting parameters are not negatively affected besides it help in precise consumption of plant water requirement.
3. The present study revealed that the combined foliar application of kaolin @4% solution as an antitranspirant and micronutrients B as Boric Acid (H_3BO_3), Mn as Manganese Sulphate ($MnSO_4$), Se as Sodium Selenate @100 ppm seperately at 80% level of ET moisture (I_1F_2) performed the best compared with all other treatments. This treatment combination is a helpful option to alleviate the heat stress of summer tomato with promising return in terms of growth, yield and quality.
4. At 60% level of ET irrigation application of kaolin and micronutrients help to improve the yield status of summer tomato.

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APPENDICES

Appendix I. Characteristics of the soil of experimental field analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the soil of experimental field

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

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	13.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	33

Source: SRDI, 2013

Appendix II. Analysis of variance of the data on plant height at different days after transplanting (DAT) of summer tomato BARI - 4 on kaolin and micronutrients at different moisture levels

Source of variation	Degrees of freedom (df)	Mean Square of plant height at		
		30 DAT	45 DAT	Final harvest(75DAT)
Moisture levels (A)	2	80.558*	50.113*	213.187**
Kaolin and micronutrients (B)	2	78.433*	60.766*	201.902**
Interaction (A×B)	4	73.234*	57.975*	139.220**
Error	18	23.421	16.883	29.378

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability

Appendix III. Analysis of variance of the data on different plant growth parameters of summer tomato BARI - 4 on kaolin and micronutrients at different moisture levels

Source of variation	Degrees of freedom (df)	Mean Square of				
		Foliar coverage (cm)	Length of internode (cm)	No. of leaves per plant	Leaf length (cm)	No. of effective branches per plant
Moisture levels (A)	2	44.217**	13.873**	36.266**	20.597*	24.977*
Kaolin and micronutrients (B)	2	32.527*	12.073**	27.169*	19.633*	22.544*
Interaction (A×B)	4	23.023*	8.227*	20.922*	13.795*	18.236*
Error	18	7.623	2.523	6.24	4.465	5.078

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability

Appendix IV. Analysis of variance of the data on Leaf temperature(^{0}C) of summer tomato BARI - 4 on kaolin and micronutrients at different moisture levels

Source of variation	Degrees of freedom (df)	Mean Square of			
		Leaf temperature (^{0}C) before foliar spray (43 DAT)	Leaf temperature (^{0}C) after foliar spray (45 DAT)	Leaf temperature (^{0}C) before foliar spray (70 DAT)	Leaf temperature (^{0}C) after foliar spray (72 DAT)
Moisture levels (A)	2	2.047^{*}	3.567^{**}	4.714^{*}	8.215^{**}
Kaolin and micronutrients (B)	2	2.112^{*}	2.862^{*}	5.989^{*}	5.517^{**}
Interaction (A×B)	4	1.794^{*}	2.099^{*}	4.353^{*}	3.415^{*}
Error	18	0.598	0.701	1.452	1.136

* Significant at 0.05 level of probability; **Significant at 0.01 level of probability

Appendix V. Analysis of variance of the data on Canopy temperature (^{0}C) of summer tomato BARI - 4 on kaolin and micronutrients at different moisture levels

Source of variation	Degrees of freedom (df)	Mean Square of			
		Canopy temperature before foliar spray (43 DAT)	Canopy temperature after foliar spray (45 DAT)	Canopy temperatur e before foliar spray (70 DAT)	Canopy temperatu re after foliar spray (72 DAT)
Moisture levels (A)	2	8.318	4.750	5.194	14.021^{**}
Kaolin and micronutrients (B)	2	6.308	2.110	2.123	10.628^{**}
Interaction (A×B)	4	6.363	1.129	1.876	1.150^{**}
Error	18	1.194	0.360	0.624	0.104

* Significant at 0.05 level of probability; **Significant at 0.01 level of probability

Appendix VI. Analysis of variance of the data on different parameters of summer tomato BARI - 4 on kaolin and micronutrients at different moisture levels

Source of variation	Degrees of freedom (df)	Mean Square of			
		Relative water content (%)	No. of fruit cluster per plant	Total Fruit per plant	Fruit diameter (mm)
Moisture levels (A)	2	686.226**	0.654*	267.906**	98.936**
Kaolin and micronutrients (B)	2	597.467**	0.502*	190.493*	89.951**
Interaction (A×B)	4	57.585*	0.455*	141.131*	48.768*
Error	18	21.238	0.143	46.122	15.443

* Significant at 0.05 level of probability; **Significant at 0.01 level of probability

Appendix VII. Analysis of variance of the data on fruit quality parameters of summer tomato BARI - 4 on kaolin and micronutrients at different moisture levels

Source of variation	Degrees of freedom (df)	Mean Square of			
		Fruit length (mm)	Fruit firmness (Neuton)	Inner fruit tempt. (^{0}C)	Chlorophyll content (%)
Moisture levels (A)	2	33.389**	1.477*	7.003**	102.698*
Kaolin and micronutrients (B)	2	29.186*	1.318*	8.758**	214.705*
Interaction (A×B)	4	20.602*	0.989*	4.051*	84.996*
Error	18	6.867	0.328	1.264	28.223

* Significant at 0.05 level of probability; **Significant at 0.01 level of probability

Appendix VIII. Analysis of variance of the data on fruit quality paramrters of summer tomato BARI - 4 on kaolin and micronutrients at different moisture levels

Source of variation	Degrees of freedom (df)	Mean Square of			
		Fruit P^H	Vitamin-C (mg per 100 g)	Total Soluble Solid (brix%)	Yield (kg) /plant)
Moisture levels (A)	2	0.038^{**}	30.405^{**}	3.643^{*}	0.207^{*}
Kaolin and micronutrients (B)	2	0.012^{*}	44.177^{**}	3.457^{*}	0.200^{*}
Interaction (A×B)	4	0.028^{**}	6.144^{**}	2.658^{*}	0.178^{*}
Error	18	0.003	0.908	0.878	0.064

* Significant at 0.05 level of probability; **Significant at 0.01 level of probability