EFFECT OF NITROBENZENE ON PLANT GROWTH, YIELD AND MINERALS CONTENT OF TOMATO

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EFFECT OF NITROBENZENE ON PLANT GROWTH, YIELD AND MINERALS CONTENT OF TOMATO

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*This is to certify that the thesis entitled **"EFFECT OF NITROBENZENE ON PLANT GROWTH, YIELD AND MINERALS CONTENT OF TOMATO"** submitted to the Department of agricultural chemistry, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science** in **Agricultural chemistry**, embodies the result of a piece of bona fide research work carried out by **NAHID SULTANA,** Registration number: **12-04984** 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 duly been acknowledged.

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Dedicated To

My Beloved Parents

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The Author

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ABSTRACT

The experiment was conducted at the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka 1207, during the period from November 2017 –August 2018 to find out the effect of nitrobenzene on plant growth, yield and minerals content of tomato. The experiment comprised of two factors. Factor 1- tomato varieties, V_1 (BARI Tomato- 1) and V_2 (BARI Tomato-2) and factor 2- Plant Growth Retardant nitrobenzene doses (4 Doses): T_0= 0 mL, T_1=1.5 mL, T_2= 2 mL, T_3= 2.5 mL was outlined in Completely Randomized Block Design (RCBD) with four replications and there were all together 32 plots. Application of nitrobenzene significantly influenced the height, yield and minerals content of tomato. The highest plant height was found from V_1 (97.25 cm) and T_0 (97.5 cm) whereas the shortest from V_2 (85.25 cm) and T_3 (76.00 cm) at harvesting time. In case of treatment combination, the tallest plant (95.5 cm) was found in V_1T_0 as well as the shortest plant (76.0 cm) was found in V_1T_3 at final harvest time. Considering variety, maximum yield per hectare (70.98 t) was observed in V_2 and minimum (59.0 t) in V_1. In case of nitrobenzene treatment, maximum yield per hectare (82.62 t) was observed in T_2 and minimum (46.96 t) in T_3. In case of combined effect of variety and nitrobenzene doses, maximum fruit yield per hectare (93.85 t) was observed in V_2T_2 and minimum (40.4) in V_1T_3. For nutrient analysis, combined effect of variety and nitrobenzene doses V_2T_2 observed maximum nutrient content, nutrient content (K 2.47%, Na 0.12% and P 0.521%) and Ca content in V_2T_1 performed highest nutrient where minimum (K 0.95%, Na 0.07%, Ca 0.03% and P 0.421%) in V_1T_3. From this experiment, 2 mL dose of nitrobenzene and variety V_2 (BARI Tomato-2) performed best yield and minerals content.

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Abbreviations

Abbreviation	Full word
AEZ	Agro –Ecological Zone
ANOVA	Analysis of variance
et al.	And others
@	At the rate
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
cm	Centimeter
CCC	Cycocel
DAS	Day After Sowing
DAT	Day's after transplanting
°C	Degree Celsius
°F	Degree Fahrenheit
df	Degrees of freedom
DMRT	Duncan's Multiple Range Test
BD	Bangladesh
etc.	Etcetera
FAO	Food And Agriculture Organization of United Nations
GA	Gibberellic acid
g	Gram
ha	Hectare
P^H	Hydrogen ion cone.
IAA	Indole acetic acid
kg	Kilogram
LSD	Least significance difference
m	Meter

NAA	Naphthalene acetic acid
PBZ	Paclobutrazol
%	Percent
CV%	Percentage of coefficient of variance
PGR	Plant Growth Regulators
t	Ton (1000 kg)

CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) belongs to the family Solanaceae is one of most popular and nutritious vegetables of Bangladesh (Mondal *et al*., 2011). The centre of origin of the genus Solanum is the Andean zone particularly Peru-Ecuador-Bolivian areas (Salunkhe *et al*., 1987), but cultivated tomato originated in Mexico. Tomato is one of the most highly praised vegetables consumed widely and it also a major source of vitamins and minerals. It is one of the most popular salad vegetables and is taken with great relish. Therefore Tomato is cultivated all over the country due to its adaptability to wide range of soil and climate (Ahmad, 1976). Tomato ranks top of the list of canned vegetables and next to potato and sweet potato in the world vegetable production (FAO STAT, 2013). Food value of tomato is very rich due to the higher contents of vitamins A, B and C including calcium and carotene (Bose and Som, 1990). It is widely employed in cannery and made into soups, conserves, pickles, ketchup, sauces, juices etc. Tomato juice has become an exceedingly popular appetizer and beverage.

Yield of this crop in our country is very low compare to advanced countries (Sharfuddin and Siddiquc, 1985). The present leading tomato producing countries of the world are China, United States of America, India, Egypt, Turkey, Iran, Italy, Mexico, Brazil and Indonesia (FAO, 2012)

It is considered as ‘poor man’s apple’ because of its attractive appearance and very high nutritive value, containing vitamin A, vitamin C (Thompson and Kelly, 1957) and minerals like calcium, potassium etc. Nutritional value of red tomatoes (raw) per 100 g contains 18 kcal energy, 4.0 g carbohydrates, and 2.6 g sugars, 1.0 g dietary fiber, 0.2 g fat, 1.0 g protein, 95 g water, 13 mg vitamin C (Zhang *et al.*, 2009).

Tomato universally treated as ‘‘Protective Food”, is being extensively grown as annual plant. Tomato is also rich in medicinal value. It also contains organic acids like citric, malic and acetic acids which is found in fresh tomato fruit, promotes gastric secretion, acts as a blood purifier and works as intestinal antiseptic (Pruthi, 1993).

Tomato is a rich source of lycopene and vitamins. Lycopene may help counteract the harmful effects of substances called free radicals, which are thought to contribute to age-related processes and a number of types of cancer, including, but not limited to, those of prostate, lung, stomach, pancreas, breast, cervix, colorectal, mouth and esophagus (Masroor *et al.,* 1988).

In Bangladesh, the recent statistics shows that it has great demand throughout the year but its production is mainly concentrated during the winter season. Recent statistics showed that tomato covered 75602 acres of land and the total production was approximately 413610 metric tons (BBS, 2015). While the production 69.41 t ha^{-1} in USA, 21.27 t ha^{-1} in India, 31.13 t ha^{-1} in China and 65.45 t ha^{-1} in Japan (FAO. 2004). The yield of tomato in our country is not satisfactory in comparison to its requirement. The low yield of tomato in Bangladesh; however, is not an indication of low yielding ability of this crop, but of the fact that low yielding variety, low standard crop management practices and lack of better technologies.

Plant growth regulators (PGRs) are used extensively in crop production to improve plant growth and yield by increasing fruit set, fruit number and weight. They play significant roles in the development of tomato fruit (Srivastava and Handa, 2005). Use of plant growth regulators had improved the production of tomato and other vegetables in respect of better growth and yield (Saha, 2009). Auxins are identified to affect parthenocarpy, fruit setting and fruit size (Matlob and Kelly, 1975; Rappaport, 1957; Osborne and Went, 1953). GA_3 is one of the important growth stimulating hormones which enhance cell division and cell elongation thus help in the growth and development of plants. GA_3 increases the leaves size, stem length and fruit set (Serrani *et al*., 2007). Cytokines (CKs) are important plant hormones which are known to be key regulators of various aspects of plant growth and development, including cell division, leaves senescence, lateral stem and root formation, stress tolerance and nutritional signaling (Argueso et al., 2009).

Plant growth substances are another factor for growth and development of tomato plant. It plays an important role in flowering, fruit setting, ripening and physiochemical changes during storage of tomato. Plant growth retardants are used to retard the shoot length of plants without changing developmental patterns or evoke phototoxic effects. Application of IAA as foliar sprays or to the growing media of tomato plants had a stimulatory effect on plant growth and development (Hathout *et al.,* 1993). On the other hand gibberelic acid (GA_3) plays role on controlling fruit setting, harvest, fruit drop, increasing fruit yield and extending shelf-life (Adlakha *et al.,* 1965). Fruit set in tomato was successfully improved by application of NAA and IAA (Mukherji and Roy, 1966 and Howlett, 1941). In fact the use of growth regulators had improved the production of tomato including other vegetables in respect of better growth and quality, which ultimately led to generate interest between the scientists and farmers for commercial application of growth regulators. This has been achieved not only by reducing cell elongation but also by lowering the rate of cell division and regulating the plant height physiologically. Most plant growth retardants inhibit the formation of gibberellins (GAs) and can thus be used to reduce unwanted shoot elongation. One of these retardant is nitrobenzene.

Many investigations on the physiological effect of new synthetic bio-regulators of retardant type have been reported during the last few years. One of these retardant is nitrobenzene. Nitrobenzene is an organic compound with the chemical formula $C_6H_5NO_2$. It is water-insoluble pale yellow oil with an almond-like odor. When it freezes it turns to greenish-yellow crystals. It is produced on a large scale from benzene as a precursor to aniline. In the laboratory, it is occasionally used as a solvent, especially for electrophilic reagents. Morphological and anatomical effects of the triazoles include reduced shoot elongation and trichome length, enhanced chloroplasts and increased root growth. After treatment, reduction of plant height is accompanied by an increased radial expansion of the stem. Biochemical effects of the Nitrobenzene include detoxification of active oxygen, reduced gibberellin synthesis and increased chlorophyll content (Singh *et al.,* 2015).

Growth retardants have some other physiological effects; they could induce the more intense accumulation of compounds that influence taste, color and flavor, thus improving the quality and the commercial value of the products. Growth retardant of nitrobenzene are used widely in agriculture, especially, on cereal crops, to prevent their lodging and decrease grain loss at ripening and enhance plant tolerance to environmental stress, without affecting positively growth and production (Lolaei *et al.*, 2013).

Considering the above mentioned fact, the present investigation was undertaken with the following objectives:

- To evaluate growth and yield parameters of two tomato varieties under different doses of nitrobenzene,
- To find out the minerals content of tomato using plant nitrobenzene.

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the important popular and nutritious vegetable in Bangladesh and other countries of the world and it has drawn attention by the researchers for it diversified way of consumptions. It is adapted to a wide range of climates ranging from tropics to within a few degree of the Arctic Circle. However, in spite of its broad adaptation, production is concentrated facing in diverse type biotic and abiotic factors. Variety and plant growth retardant nitrobenzene play an effective role for the growth and yield of tomato. But very few research works available related to growth, yield and development of tomato due to variety and nitrobenzene. The research work so far done in Bangladesh is not adequate and conclusive. However, some of the important and informative works and research findings related to variety and nitrobenzene in tomato, so far been done at home and abroad, have been reviewed in this chapter. Some of the available research works have been reviewed here:

2.1 Growth and yield response of tomato

Husen *et al.* (2012) showed that paclobutrazol accelerate the induction of flowering as indicated by the number of flowering plant, the more flower, faster emergence, rate of flowers, the more petals, but the length and width of inflorescences is shorter than the control.

Martinez-Fuentes *et al.* (2013) reported that the effectiveness of PBZ in promoting flowering in Citrus depends on the fruit load since the tree showed a cultivar-dependant threshold value above which PBZ is unable to promote flowering.

Three separate field experiments were conducted by Olaoye *et al*. (2009) at the Teaching and Research Farm, University of Ilorin, Nigeria on an alfisol with low inherent fertility status to study the effect of two conventional tillage methods on yield of tomato (*Lycopersicon esculentum*). The conventional tillage treatments were used to assess the response of the varieties to four N-Fertilizer regimes, two different growing seasons and two moisture regimes respectively. Roma (check variety) significantly yielded higher than other varieties under both N-Fertilizer regimes and growing seasons while Periondonta was superior for fruit yield under moisture regime.

Olaniyi *et al*. (2010) conducted experiments at the Teaching and Research farm of the Faculty of Agricultural Sciences, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso to evaluate the growth, fruit yield and quality of seven varieties of tomato in the Guinea Savannah zone of South West Nigeria. The varieties tested were, DT 97/162A(R), DT 97/215A, Tropical, Roma VF, UC82B, Ibadan local and Ogbomoso local. Growth, yield, mineral content and quality attributes of tomato were assessed. The results showed that DT 97/162A(R) gave the highest height whereas Ogbomoso local recorded the highest number of leaves at 6 weeks after transplanting. Higher fruit yield was recorded from UC82B, closely followed by Ibadan and Ogbomoso local. Although, there is inconsistence in the results of the nutritional compositions of tomato fruits, the local varieties (Ogbomoso and Ibadan Local) closely followed by UC82B recorded most of the nutritional values more than the other varieties. Therefore UC82B, Ibadan and Ogbomoso local in that descending order are better in terms of fruit yield and quality.

Three processing and six fresh market tomato varieties were evaluated by Tigist *et al*. (2012) for yield and related traits. The tomato varieties harvested at "mature green” stage were evaluated for changes in physical quality characteristics during the storage period of 32 days under ambient conditions.

The experiment was conducted by Hossain *et al*. (2013) at Agricultural Research Station, Thakurgaon, Bangladesh to observe the effect of sowing dates on yield of tomato genotypes. Three sowing dates were considered as factor A and tomato variety viz., BARI Tomato-2, BARI Tomato-3, BARI Tomato-4, BARI Tomato-9 and BARI Hybrid Tomato-4 considered as factor B. Among the variety, BARI Tomat-2 produced the highest (68.12 t/ha) marketable yield followed by BARI Tomato-9 (56.16 t/ha) and BARI Tomato-3 while BARI Tomato-4 gave the lowest (36.91 t/ha) marketable yield.

Biswas *et al*. (2015) conducted an experiment at Agronomy Farm of the Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar Dhaka to study growth and yield responses of tomato varieties. Experiment consisted of four varieties, viz. BARI Tomato-4 (V_1), BARI Tomato-5 (V_2), BARI Tomato-7 (V_3) and BARI Tomato-9 (V_4). Tallest plant (101.3 cm), maximum number of leaves (114.1/plant) and maximum number of branches (10.0/plant) was found from BARI Tomato-7. While maximum number of flowers (6.1/cluster), number of fruits (5.0/cluster), number of clusters (17.9/plant) were found from BARI Tomato-9. However, maximum fruit diameter (20.1 cm), individual fruit weight (115.9 g), yield (34.7 kg/plot and 95.9 t/ha), number of locule (4.4/fruit) were also found from BARI Tomato-7. It was revealed that the virus infestation, fruit length and Total soluble solid (TSS) were statistically identical among the varieties under this study.

2.2 Effect of growth retardants on growth parameters

Dhanashree and Rajashree were determined by Bhosle *et al*. (2002) in a field experiment conducted in Rahuri, Maharashtra, India during the summer of 1997.The number of flowers per cluster, fruit weight and marketable yield increased with increasing rates of the plant growth regulators. Treatment with 30 ppm gibberellic acid resulted in the tallest plants, whereas treatment with 45 ppm gibberellic acid resulted in the highest number of primary branches of Dhanashree (4.16) and Rajashree (5.38), respectively.

Meena (2008) conducted an experiment with foliar spray of GA_3 and found GA_3 at 50 or 75 ppm recorded significantly lower fruit drop percentage. Significantly higher total soluble solids, ascorbic acid content and TSS/acid ratio and lower acidity percentage were observed with application of GA_3 at 50 ppm. The maximum benefit-cost ratio of 5.57 was recorded with application of GA_3 at 50 ppm followed by NAA at 50 ppm (3.04). Significantly more plant height and plant spread at 60 DAT and at harvest, leaf area per plant at harvest, number of flowers per plant, fruit set percentage, number of fruits per plant, average fruit weight and fruit yield and lower fruit drop percentage were recorded with application of boron as foliar spray @ 2.0 kg/ha.

Kaushik *et al.* (1974) conducted an experiment applied growth regulator GA_3 at 1, 10 or 100 mg L^{-1} on tomato plants at two leaf stage and then at weekly interval until 5 leaf stage. They found that growth regulator increased the number and weight of fruits per plant at the highest concentration.

Choudhury and Faruque (1972) indicated that the percentage of seedless fruit increased with the increase in growth regulator concentration from 50 ppm to 100 ppm. However the fruit weight was found to decrease by GA_3.Gustafson (1960) spraying of growth regulator on tomato flower and flower buds of the first three clusters (35 and 70 ppm) and established that GA_3 improved fruit set but reduced fruit weight of tomato.

Rapport (1960) proved that GA_3 had no significant effect on fruit weight and size either at cool (10^0C) or warm (23°C) night temperatures; but it strikingly waned fruit size at an optimum temperature (17^0C).

2.3 Effect of plant growth regulators on physiological parameters

Tari (2003) showed that the inhibitory effect of paclobutrazol on the abaxial stomatal conductances became more pronounced with time during the light period but the adaxial surfaces displayed similar or slightly higher conductance than those of the control. The transpiration rate on a unit area basis did not change significantly or increased in the treated leaves thus the reduced water loss of paclobutrazol-treated plants due to the reduced leaf area. Stomatal conductance of the adaxial surfaces responded more intensively to exogenous abscisic acid and the total leaf conductance decreased faster with increasing ABA concentration in the control than in the paclobutrazol-treated leaves.

Tekalign and Hammes (2005) reported that foliar application gave a higher rate of net photosynthesis than the soil drench. Paclobutrazol significantly reduced total leaf area and increased assimilate partitioning to the tubers. Study also showed that paclobutrazol is effective to suppress excessive vegetative growth, favor supply of assimilate to the tubers, increase tuber yield which result into improved tuber quality.

Sharma *et al.* (2011) found that application of PBZ reduced the membrane injury index and increased relative water content, photosynthetic rate, and pigments content.

Verma *et al.* (2014) conducted an experiment to study the effect of varying levels of NAA, 2, 4-D and GA_3 on growth, quality and yield of tomato and to ascertain the best concentration of NAA, 2, 4-D and GA_3 for vegetative growth and fruit quality of tomato. The experiment consisted one tomato variety viz .kashi vishesh (H-86) and different levels of NAA (15, 30, 45 ppm), 2, 4-D (5, 10, 15 ppm) and GA_3 (20, 30, 40 ppm) of different concentrations were used. The result showed maximum yield per hectare.

Yung (2000) conducted an experiment on the role of growth regulators on cold water for irrigation reduced stem elongation of plug-grown tomato seedlings. The effect of growth regulators [abscisic acid. gibberellic acid (GA_3), paclobutrazol, ethephon, IAA and silver thiosulfate] and cold-water irrigation at different temperatures (5, 15, 25, 35, 45 and 55°C) on the reduction of stem elongation of plug-grown tomato seedlings was investigated. The stem length increased while the total dry weight decreased when the water temperature was N. higher or lower than the room temperature (about *25* °C). The differences in stem diameter were non-significant at several water temperatures. The seedling index (shoot dry weight per stem length) was higher when irrigated with cold water at *5* degrees C than with water at room temperature. Paclobutrazol, ethcphon and GA_3 reduced the stem length of the tomatoes at several water temperatures. Cold-water irrigation with the addition of 0.1-0.5 mM silver thiosulfate (ethylene biosynthesis inhibitor) or 1-10 ppm IAA (ethylene biosynthesis inducer) did not change stem length. This suggested that the reduction of stem elongation due to coldwater irrigation had no relationship with ethylene synthesis. However, cold-water irrigation with the addition of 1.8 ppm GA_3 or irrigation at room temperature could promote stem elongation. Irrigation at room temperature with the addition of 10-ppm paclobutrazol (GA_3 biosynthesis inhibitor) or cold water irrigation could inhibit stem elongation. The reduction in stem elongation in plug-grown tomato seedlings was due to the relationship of Gas metabolism and sensitivity.

2.4 Effect of growth regulators on morpho-physiological and structural components on productivity

Nigam *et al*. (1984) studied the effect of GA_3, B-9 and CCC in groundnut and reported that except GA_3, other growth regulators increased the number of primary and secondary branches. Mandal *et al.* (1997) indicated a significant increase in the number of branches per plant due to the application of CCC @ 100 ppm in green gram.

Woo, Yin Chow (1987) reported that paclobutrazol significantly retarded young and newly emerging vegetative shoot growth. At the final harvest, plant height was reduced from 287cm to 213cm at both rates of paclobutrazol. Reduced stem length was the major contributor to the stem shortening effect. Lateral shoot growth was also substantially shortened by 37% (2 ppm) and 53% (10 ppm) compared to the untreated. Reductions in dry weight in response to paclobutrazol were always smaller in comparison to reductions in elongation of the main stem and laterals.

Shalaby (1996) noticed the effect of cycocel (CCC [chlormequat]; at 0, 150, 300, 450 and 600 mg/litre) on the vegetative growth, photosynthetic pigments, flowering, abscission and yield and its components in chickpea cultivars. Sreekala *et al.* (2000) reported that the effect of paclobutrazol caused a complete retardation of growth and significant reduction in yield. Plant height, the number of branches and spikes per plant, and yield were highest under chlormequat (500 ppm) treatment in wheat.

Ghora *et al.* (2000) observed that the application of cycocel at 500 ppm, applied at 45 cm plant height, reduced primocane height without reducing the number of nodes, and enhanced anthesis and fruit ripening by about 10 days. Yield significantly increased by 90% without affecting berry size compared to the control or 100 ppm cycocel application.

Hunje *et al.* (1995) reported that the foliar spray of growth regulators reduced the plant height significantly over control, thereby significantly over the number of branches, number of nodes and spread per plant. Higher concentrations of CCC, TIBA, and MH helped to arrest plant height compared to low concentrations. *Ganiger et al.* (2002) observed that the number of pods per plant at 75 DAS showed maximum number (9.5). In TIBA followed by CCC 500 ppm while, least number of pods were observed in NAA 250 ppm (6.93) and control (7.20).

Yadav and Asati *et al.* (2005) noted that that effect of paclobutrazol on seed treatment and seed germination, vegetative growth, flowering, fruit set and development; fruit yield, fruit quality and resistance to biotic and abiotic stresses in horticultural crops. Tekalign and Hammes (2005) reported that paclobutrazol reduced the partitioning of assimilate to the leaves, stems, and roots and stolons and increased allocation to the tubers. Although paclobutrazol decreased the total biomass production but it improved tuber yield by partitioning more assimilates towards the tubers.

Mahgoub *et al. (*2006) indicated that foliar application of most paclobutrazol treatments significantly decreased plant height compared with control treatment. However, number of branches, fresh weight and dry weight of leaves per plant were increased Kalyankar et al. (2008) showed that all the concentration of GA_3, NAA and CCC increased the number of pods per plant, number of grains per pod, 100 seed weight, harvest index, grain yield and biological yield significantly than the control.

Kshirsagar *et al.* (2008) observed that application of cycocel @ 150 ppm was found beneficial in decreasing plant height, number of leaves and leaf area per plant. It was also observed that there was increase in number of nodules and number of lateral branches per plant.

Shah and Prathapasenan (2008) found that CCC at 1000 ppm increased the number of pod per plant, number of seed per pod, leading to increased seed yield per plant. CCC had no effect on the 1000 seed weight.

Setia *et al*. (2009) noted that the foliar spraying of field grown lentil plants with paclobutrazol (PBZ-5, 10 and 20 micro g/ml) significantly suppressed plant height but increased the number of primary and secondary branches with a consequent enhancement in seed yield through increased number of pods per plant. PBZ enhanced total dry matter of plants, partitioning coefficient and harvest index.

Sharma and Lashkari (2009) emphasized that the maximum number of tender pods per plant, length, width, volume and total crude protein content of pods were observed with CCC 1000 ppm. Whereas, the highest seed yield was obtained with CCC 2000 ppm.

Kashid *et al.* (2010) reported decrease in plant height with mepiquat chloride and cycocel treated plants. However, maleic hydrazide (100, 200 and 300 ppm), TIBA (25, 50and 75 ppm) and cycocel (500 ppm) remained ineffective and were at par with the control. Cycocel and mepiquat chloride are anti-gibberellin dwarfing agents, and foliar spray of these may induce deficiency of gibberellin in the plant and reduce the growth by blocking and conversion of geranyl pyrophosphate to coponyl pyrophosphate which is the first step of gibberellins synthesis (Moore, 1980). Maximum reduction in plant height was observed in mepiquat chloride treatments than any of other chemicals.

Lolaei *et al.* (2012) observed that highest fruit numbers, fruit weight, fruit set, flower number and yield of strawberry were obtained in plants treated with 90 mg L-1 PBZ. Foliar application of PBZ prior to flowering is recommended to increase the yield of strawberry.

Sarker and Rahim (2012) noted that the application of paclobutrazol was more effective in suppressing vegetative growth i.e. terminal shoot length, number of leaves and leaf area compared to control. Applications paclobutrazol at 7500 ppm produced the highest number of fruits as well as yield per plant and the heaviest fruit compared with the lowest yield in control.

Mukadam and Haldankar (2013) emphasized the use of foliar application of paclobutrazol and nutrients accelerated harvesting in karonda. All foliar sprays improved yield and quality of karonda.

Udensi *et al.* (2013) observed that treating pigeonpea seeds with paclobutrazol caused reduction in plant height and inter-nodal length, which did not translate to higher yield. However, plants raised from pigeonpea seeds soaked in 100 and 150 mg/l paclobutrazol + NAA did excellently well in both yield and yield related traits.

Ramesh *et al.* (2013) observed that the application of brassino steroid at 25 ppm, mepiquat chloride 5% and chlormequat chloride applied at 187.5g a.i/ha, 162.5g a.i/ha and 137.5g a.i/ha resulted in higher seed yield, compared to control and water spray.

Velayutham and Parthiban (2013) recorded that the number of primary and secondary rhizomes per plant, length and girth of primary and secondary rhizomes, fresh and dry weight of rhizomes, yield per plot and yield per hectare were recorded highest in CCC 500 ppm sprayed plants. For obtaining highest yield with good quality of ginger rhizomes, foliar application of CCC at 500 ppm could be recommended to the growers. Pourmohammad *et al.* (2014) reported that foliar application with cycocel also increased plant dry weight, 1000 seeds weight, harvest index and seed yield.

2.5 Effect of growth regulators on biochemical estimation

Bora and Sarma (2006) observed that the cycocel at 100 and 250 μ g-^{1} ml recorded maximum number of pods per plant and seed yield in cv. Azad-P-1 and cv. Aparna, respectively. Protein content in seeds was recorded highest at 500 μ g mL^{-1} of cycocel. Study clearly showed that judicious application of GA_3 and cycocel can increase yield and protein content in seeds of pea.

Reddy *et al.* (2009) found that the application of growth retardants and nipping at 35 DAS increased the chlorophyll content and the seed protein content did not differ significantly, though there was increase in its content MC @ 500 ppm, @ 1000 ppm, lihocin @ 500 ppm and nipping at 1 week after tendril formation significantly increased chlorophyll content and NRA at later stages which in turn increased the yield.

Bekheta and Talaat (2009) noted that an application of paclobutrazol at all the used treatments led to significantly decreased in plant height. Total carborhydrates, protein contents and mineral ions content of the produced seed were significantly increased as result of foliar application of salicylic acid, glutathione and paclobutrazol.

Zheng *et al.* (2012) observed that the CCC and PBZ treatments substantially enhanced the sucrose contents in leaves probably due to the increase of chlorophyll contents. Treatment with CCC or PBZ decreased GA but increased IAA contents in lily bulbs which might stimulate starch accumulation and formation of new scales. It is suggested that CCC or PBZ treatment is an effective method to promote carbohydrate accumulation in lily bulbs.

Hashemabadi *et al.* (2012) showed that the effect of CCC and daminozide were significant on the amount of essential oils per 100 g dried flowers and plant height (p.0.01). Interaction effects of CCC and daminozide were significant on plant height, number of flowers per plant, number of leaves per plant, flower dry weight and the amount of essential oils per 100 g dried flowers.

Ramesh and Ramprasad (2013) noted significantly increased in the seed protein content with the application of NAA (20 ppm), Brassino steroid (25 ppm), mepiquat chloride (5%), ammonium sulphate (5%) and chlormequat chloride at different concentration, compared to control and water spray.

Partovian *et al.* (2013) observed the effect of cycocel on per Carthamin decarboxylase enzyme, relative moisture content, free amino acid of proline and oil percent of two safflower varieties under deficit irrigation.

An experiment was carried out by Rahman *et al*. (2015) in pots at Bangladesh Institute of Nuclear Agriculture, Bangladesh to evaluate influence of different concentrations of GA_3 on biochemical parameters at different growth stages in order to maximize yield of summer tomato var. BINA Tomato-2. Results indicated that the highest chlorophyll and soluble protein contents were recorded when GA_3 was applied through root soaking followed by vegetative stage and the lowest was found at the flowering stage. In contrast, the highest nitrate reeducates activity was observed when GA_3 was applied at the vegetative stage and the lowest activity was recorded at the flowering stage. The highest plant height was recorded when 50 ppm of GA_3 was applied at the vegetative stage, while, the longest time to first fruit setting was required when the roots of the seedlings were soaked in 100 ppm GA_3 solution. The application of 50 ppm GA_3 by root soaking had significantly increased the number of flowers, fruits and fruit yield per plant but similar results were achieved when only 25 ppm GA_3 was applied at the flowering stage. The fruit yield of tomato per plant increased linearly with the increased number of flowers and fruits per plant. As per the above cited reviews, it may be concluded that variety and GA_3 are the important factors for attaining optimum growth and as well as highest yield of tomato. The literature revealed that the effects of variety and GA_3 have not been studied well and have no definite conclusion for the production of tomato in the agro climatic condition of Bangladesh.

Kanwar *et al.* (1976) recorded significantly increased fruit length (5.15 cm) and weight with spray of GA_3 (30 ppm) at pre-bloom stage in tomato whereas, did not notice any significant increase in fruit length of chilli with GA_3 (10 ppm) sprayed at first flower opening followed by two sprays at interval of 30 days.

The mode of action of paclobutrazol has been revealed as the consequence of inhibition in the biosynthesis of elongation growth promoting hormone gibberellins, known to be synthesized following isoprenoid pathway. The isoprenoid pathway besides synthesizing gibberellins, also partially regulate the synthesis of other important endogenous hormones such as abscisic acid (ABA) and cytokinins. Considering that the plant growth is regulated by interaction among endogenous hormones and the levels of one hormone influence the level of others, the growth inhibitory response of paclobutrazol could better be explained by changes in the levels of different hormones rather than single hormone. It can be applied to fruits trees by soil drench, truck soil-line pour, trunk injection and foliar sprays.

CHAPTER III

MATERIALS AND METHODS

3.1 Location of the experimental field

The experiment was conducted during the period from November 2017 to August 2018 at the experimental field of SAU campus and chemical analysis in the Agro-Environmental Chemistry Laboratory of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka -1207 to find out the effect of nitrobenzene on plant growth, yield and minerals content of tomato.

3.2 Soil of the experimental field

Soil of the study site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.8-6.5, ECE-25.28 (Haider, 1991). The analytical data of the soil sample collected from the experimental area which were determined from the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix II

3.3 Plant materials collection

The tomato varieties used in the experiment were "BARI Tomato-1" & "BARI Tomato-2". These are high yielding variety. The seeds were collected from Olericulture division of Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI) Joydebpur, Gazipur.

3.4 Raising of seedlings

Tomato seedlings were raised in two seedbeds of 3 m x 1m size. The soil was well prepared and converted into loose friable and dried mass by spading. All weeds and stubbles were removed and 5 kg well rotten cow dung was mixed with the soil. Five (5) gram of two varieties seeds were shown on each seedbed on in 29 October 2017. After sowing, seeds were covered with light soil. The emergence of the seedlings took place within 6 to 7 days after sowing. Weeding, mulching and irrigation were done as and when required.

3.5 Treatments of the experiment

The experiment consisted of two factors as follows:

Factor A: Two different tomato varieties:

V_1 = BARI Tomato-1 and

V_2 = BARI Tomato-2

Factor B: Four doses of Growth Retardant nitrobenzene:

T_0 = 0 mL (control)

T_1 = 1.5 mL

T_2 = 2 mL

T_3 = 2.5 mL

3.6 Design and layout of the experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) having two factors with four replications. The whole area was divided into four equal blocks. Each block was consists of 8 plots where 8 treatments were allotted randomly. There were 32 unit plots in the experiment. The size of each plot was 2 m x 1.8 m. The distance between two blocks and two plots were kept 1 m and 0.5 m respectively.

3.7 Cultivation procedure

3.7.1. Land preparation

The soil was well prepared and good tilth was ensured for commercial crop production. The land of the experimental field was ploughed with a power tiller on 02 November, 2017. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and then the land was made ready to use. The field layout and design was followed after land preparation.

3.7.2. Application of manure and fertilizers

Manures and fertilizers were applied to the experimental plot considering the recommended fertilizer doses of tomato (BARI, 2014). The fertilizers N, P and K were used in the form of urea, TSP and MoP, respectively along with cowdung and were applied following the below mentioned application procedure.

Table 1. Dose and method of application of fertilizers in tomato field

Fertilizers and Manures	Dose/ha	Application (%)			
		Basal	10 DAT	30 DAT	50 DAT
Cowdung	10 tonnes	100	----	----	----
Urea	300 kg	----	33.33	33.33	33.33
TSP	200 kg	100	----	----	----
MoP	220 kg	100	----	----	----

The total amount of cowdung, TSP and MoP were applied as basal dose at the time of final land preparation and mixed with soil properly. The total amount of urea was applied carefully in three equal installments at 10, 30 and 50 day after Transplanting (DAT).

3.7.3. Transplanting of seedlings

Healthy and uniform seedlings 28 days old were uprooted separately from the seed bed and were transplanted in the experimental plots in 08 December, 2017 maintaining a spacing of 50 cm x 50 cm between the rows and plants, respectively. This allowed an accommodation of 9 plants in each plot. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage to the roots. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.7.4. Intercultural operations

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

1. Gap filling

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

2. Weeding

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

3. Tagging

Tagged were done in each plot by different varieties and treatment with tag and rope in bamboo stick.

4. Application of growth retardant

After 15 days of seedling transfer from seed bed to main field 1^{st} treatment application was done. After 20 days later 2^{nd} treatment applied when tomato plants were at flowering stage. The 3^{rd} dose applied after 20days later at fruiting stage.

5. Staking

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

6. Irrigation

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

7. Plant protection

From seedling to harvesting stage tomato is very sensitive to diseases and pest. After getting a maturity stage protection measure was taken against diseases and pests. So that, any insect or fungal infection and insect infestation cannot appear in the plant. To remove fruit loss from birds netting was done through the crop field.

8. Harvesting

Fruits were harvested at 15 days intervals during early ripe stage when they attained slightly red color. Harvesting was started from 15 March, 2017 and was continued up to end of 29 April 2017.

9. Data collection

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

9.1. Plant height

The plant height (cm) was measured in centimeters from the base of plant to the terminal growth point of main stem of selected plants were recorded at 10 days interval starting from 20 days of planting up to 60 days to observe the plant height. The average height was computed.

9.2. Number of leaves plant^{-1}

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

9.3. Number of branches plant^{-1}

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

9.4. Number of clusters plant^{-1}

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

9.5. Days to 1st flowering from transplanting

The number of flowers was counted at 1st flowering from transplanting to the plants 20, 40 and final harvest after transplanting from the average number of flower produced plant^{-1} was recorded.

9.6. Number of flowers cluster^{-1}

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

9.7. Number of flowers plant^{-1}

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

9.8. Number of fruits cluster^{-1}

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

9.9. Number of fruits plant^{-1}

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

9.10. Length and diameter of fruit

Among the harvested fruit during the period from first to final harvest the length and diameter of fruits were measured by slide calipers. The length and diameter of fruit was calculated by making the average of five fruits from each harvesting.

9.11. Fresh weight of fruit

Among the total number of fruit harvested during the period from first to final harvest, the weight was calculated from total weight of fruits was divided by total number of fruits of every harvest and finally making the average was made from each harvesting data.

9.12. Dry matter content of fruit (%)

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

9.13. Yield plot^{-1}

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

9.14. Yield (t ha^{-1})

It was measured by the following formula:

Yield of tomato (t/ha) = Fruit yield per unit plot (kg) x 1000 /Area of unit plot in square meter x 1000

10. Chemical Analysis

10.1 Sample Preparation

For each variety, two fresh tomatoes were cut into four piece and dried in sunlight for 5 to 6 days and placed in oven maintained at 60^0C for two weeks. After drying, these tomatoes were grinding. From each variety 0.5g grinding sample were collected for extract preparation and stored in oven.

10.2 Extract Preparation

Fruit samples were dried in an oven at 70^0C to obtain constant weight. Oven-dried samples were ground in a Wiley Hammer Mill, passed through 40 mesh screens, mixed well and stored in plastic vials. Exactly 1g oven-dried samples of different vegetables were taken in digestion tube. About 10 mL Di-acid mixture ($HCLO_4$ and HNO_3 = 2:1) was taken in a digestion tube waited for 20 minutes and then transferred to a digestion chamber and continued heating at 100^0C. The temperature was increased to 365^0C gradually to prevent frothing (50^0C steps) and left to digest until yellowish color of the solution turned to whitish color. Then the digestion tubes were removed from the heating chamber and allowed to cool to room temperature. About 50 mL of de-ionized water was carefully added to the digestion tubes and the contents filtered through What man no. 40 filter paper into a 100 mL volumetric flask and the volume was made up to the mark with distil water. The samples were stored at room temperature in clearly marked containers.

10.3 Minerals Content Analysis

10.3.1 Determination of Potassium

Potassium content in the digested fruit sample was determined by the flame photometer (Model No: PFP7).

10.3.2 Determination of Calcium

Calcium content in the digested fruit sample was determined by the flame photometer (Model No: PFP7).

10.3.3 Determination of Sodium

Sodium content in the digested fruit sample was determined by the flame photometer (Model No: PFP7).

10.3.4 Determination of phosphorus

Phosphorus content in the digested fruit sample was determined by the Ascorbic acid blue color method with the help of spectro photometer (Model No: UV- 1800 240V).

10.4 Statistical Analysis

The data in respect of growth, yield contributing characters and yield were statistically analyzed to find out the statistical significance of the experimental results. The means for all the treatments were calculated and the analyses of variance for all the characters were performed by LSD test. The analyses were done following the software STATISTIX 10. The significance of the difference among the means was evaluated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

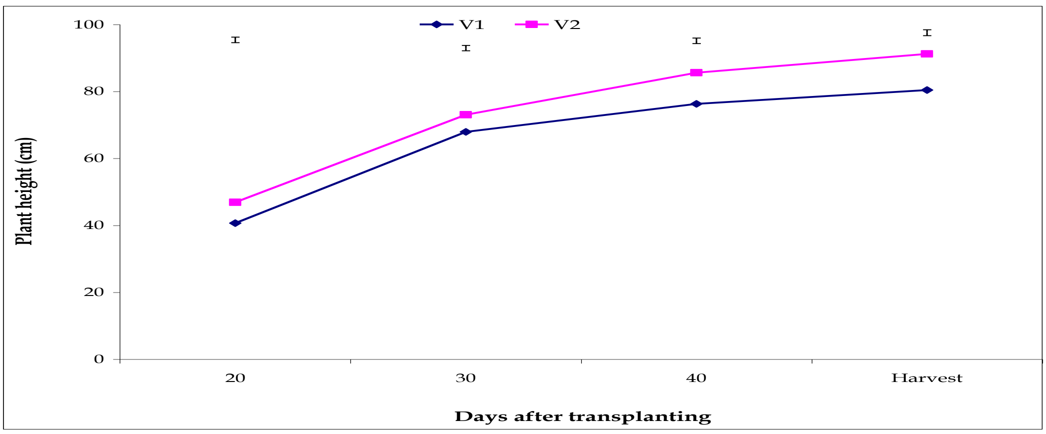
CHAPTER IV

RESULTS AND DISCUSSION

The research work on ‘Effect of nitrobenzene on plant growth, yield and minerals content of tomato’ was undertaken in the Department of Agricultural chemistry, Sher-e-Bangla Agricultural University, Dhaka. The experimental results on plant growth, yield and minerals content (%) are described as follows:

4.1. Plant height (cm)

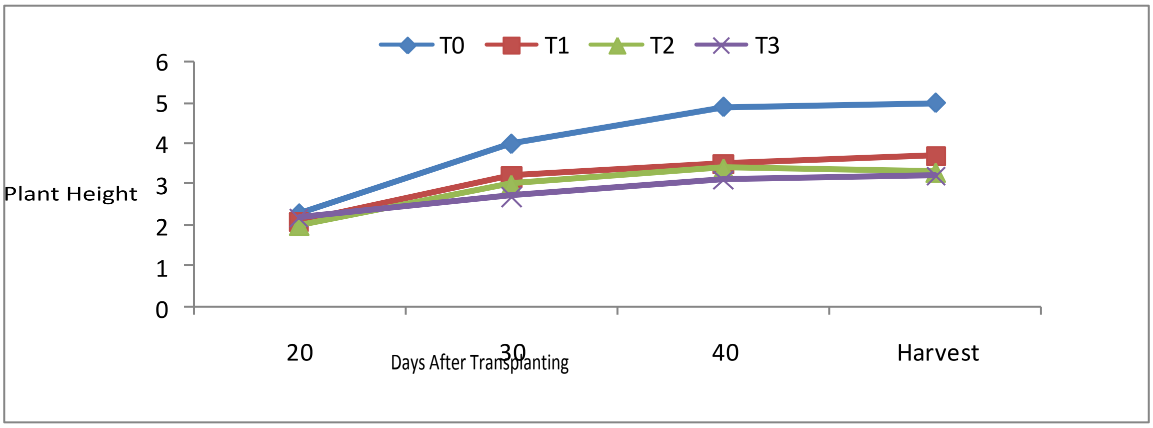
Plant height (cm) is one of the most important growth parameters in tomato which is positively correlated with yield and the growing conditions significantly influenced this trait. The difference in varieties for plant height (cm) was found significant also. Highly significant differences exist among different varieties with regard to plant height (cm) at 20 days, 30 days, 40 days and final harvest after transplanting. Significant plant height (cm) was observed from 20 days to final harvest after transplanting in all the varieties (Appendix I). The mean plant height ranged from 87.75 cm to 97.50 cm. The tallest plant was found from V_2 (97.50 cm) whereas the shortest from V_1 (76.00 cm) at final harvest after transplanting (Figure 1). Olaniyi *et al. (*2010) also found that plant height varied due to the varietal differences. It was observed that the tallness, shortness and other morphological differences are varietal characteristics, which are controlled and expressed by certain genes.



Here, V_1: BARI Tomato-1; V_2: BARI Tomato-2

Figure 1. Performance of different tomato varieties on plant height (cm) at different days after transplanting

Plant height was significantly affected by nitrobenzene doses (Appendix I). Plant height of tomato varieties exposed statistically significant inequality among control and different doses of nitrobenzene doses at 20, 30, 40 and final harvest (Figure 2). The tallest plant (97.50 cm) was recorded at (T_0) and the shortest plant (76.00 cm) was found from (T_3) at final harvest after planting (Figure 2). Similar results were observed by Nangare *et al*. (2015) in tomato. This may be due to enhanced photosynthesis and respiration due to the favorable micro-climatic conditions in the shade net house.



Here, T_0: 0 mL, T_1: 1.5 mL, T_2: 2 mL, T_3: 2.5 mL

Figure 2. Effect of different doses of nitrobenzene on plant height (cm) at different days after transplanting

In case of combination treatment significant variation in plant height (cm) was observed which indicated the influence of growing condition on plant height of different varieties (Appendix I). The tallest plant (97.50 cm) was found in 2 ml application of nitrobenzene and BARI tomato-2 variety (V_2T_2) as well as the shortest plant (76.0 cm) was found in BARI tomato-2 variety with 2.5 ml application of nitrobenzene treatment (V_1T_3) at final harvest time (Table 2).

Table 2. Interaction effect of different varieties and nitrobenzene doses on plant height of tomato at different days after transplanting (DAT)

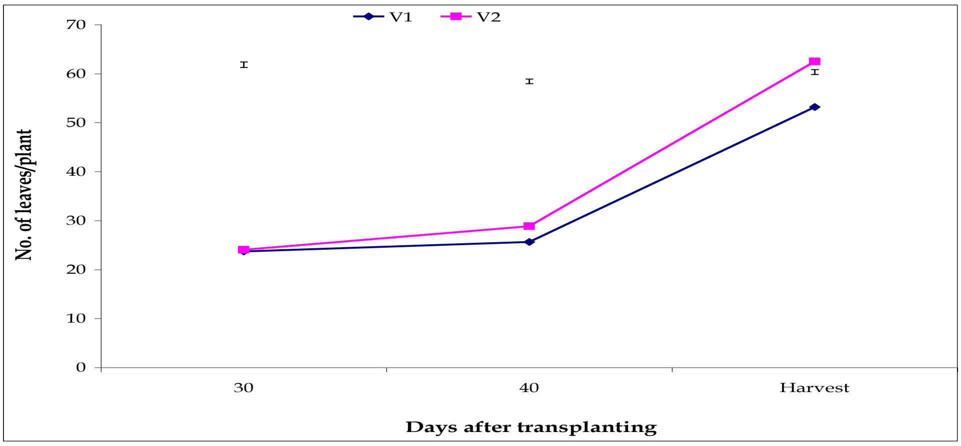
Treatment combination	Plant height (cm) at different DAT			
	20	30	40	Final harvest
V_1T_0	57.00	77.67	87.75 a	97.50 a
V_1T_1	41.00	69.00	78.00 c	79.75 d
V_1T_2	43.00	72.67	82.00 b	87.25 bc
V_1T_3	37.75	63.42	81.50 b	87.75 a
V_2T_0	46.00	72.92	86.50 a	89.50 b
V_2T_1	49.00	70.67	73.50 e	76.00 e
V_2T_2	50.00	76.09	79.75 a	86.75 a
V_2T_3	42.75	68.75	80.75 bc	85.25 c
$LSD_{0.05}$	3.06	2.88	3.05	3.21
Level of significance	NS	NS	*	*
CV (%)	4.75	2.78	2.56	2.54

*Here, V_1: BARI Tomato-1; V_2: BARI Tomato-2 and Here, T_0: 0 mL, T_1: 1.5 mL, T_2: 2 mL, T_3: 2.5 mL

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

4.2. Number of leaves per plant

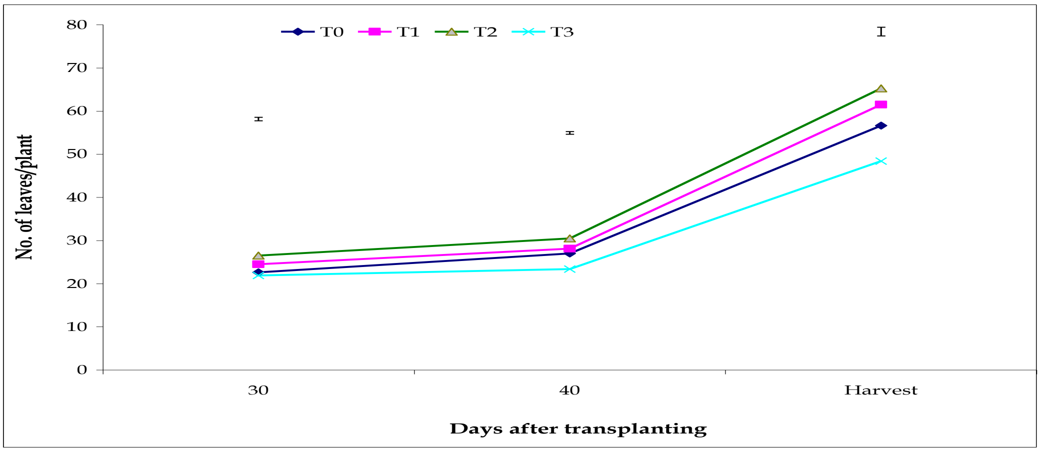
Leaves are very important vegetative organs, as they are chiefly concerned with the physiological processes, photosynthesis and transpirations. Thus it influenced the growth of a plant very much and is positively correlated with the yield of a plant. The number of leaves per plant of tomato significantly varied among the varieties (Appendix II). Highly significant differences exist between different of varieties with regard to number of leaves at 30 DAT, 40 DAT and final harvest after transplanting. The maximum number of leaves (62.5) was found from V_2 (BARI-2) and minimum (53.19) from V_1 (BARI-1) at final harvest time (Figure 3). Similar results had been reported by Ahmed *et al.*, (1976). Hossain (2007) observed highly significant variation in respect of number of leaves per plant in Raton.



Here, V_1: BARI Tomato-1; V_2: BARI Tomato-2

Figure 3. Performance of different tomato varieties on number of leaves per plant at different days after transplanting

In case of nitrobenzene doses on number of leaves per plant of tomato, significant variation in number was observed. The maximum number of leaves (65.25) was found from T_2 and minimum (48.38) from T_3 (Figure 4).



Here, T_0: 0 mL, T_1: 1.5 mL, T_2: 2 mL, T_3: 2.5 mL

Figure 4. Effect of nitrobenzene doses on number of leaves per plant at Different DAT in tomato

In case of combined effect significant variation was observed in the number of leaves per plant (Appendix II). The maximum number of leaves (72.75) was found from BARI Tomato-2 variety with 2mL nitrobenzene doses (V_2T_2) and minimum (46.0) from BARI Tomato -1 with 2.5 mL application of nitrobenzene (V_1T_3) at harvest time (Table 3).

Table 3. Interaction effect of different varieties and nitrobenzene doses on number of leaves per plant of tomato at different days after transplanting (DAT)

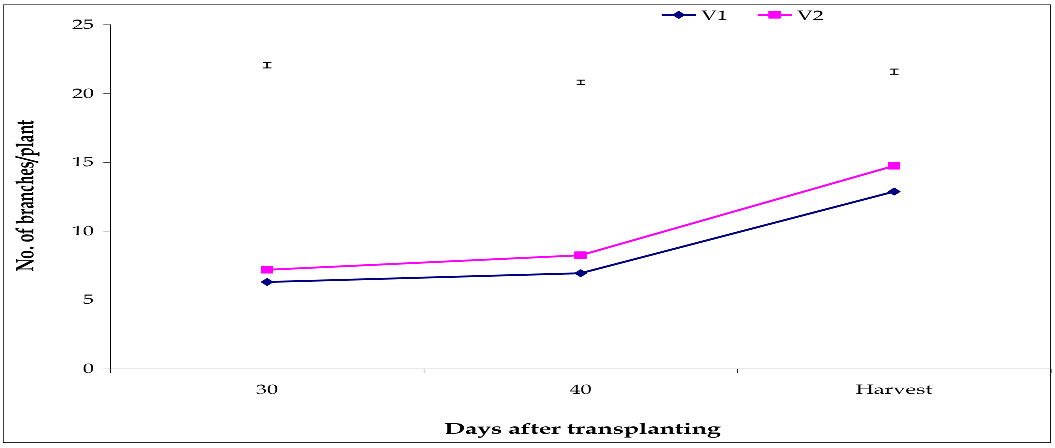
Treatment combination	No. of leaves per plant at different DAT		
	30	40	Final harvest
V_1T_0	22.25	25.75 e	52.75 d
V_1T_1	24.50	26.75 de	57.00 c
V_1T_2	26.25	27.50 cd	57.75 c
V_1T_3	21.75	22.50 g	46.00 e
V_2T_0	23.00	28.20 c	60.50 c
V_2T_1	24.50	29.50 b	66.00 b
V_2T_2	26.75	33.50a	72.75 a
V_2T_3	22.00	24.25 f	50.75 d
$LSD_{0.05}$	1.64	1.24	4.18
Level of significance	NS	**	**
CV (%)	4.68	3.09	4.91

*Here, V_1: BARI Tomato-1; V_2: BARI Tomato-2 and Here, T_0: 0 mL, T_1: 1.5 mL, T_2: 2 mL, T_3: 2.5 mL

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

4.3 Number of branches per plant

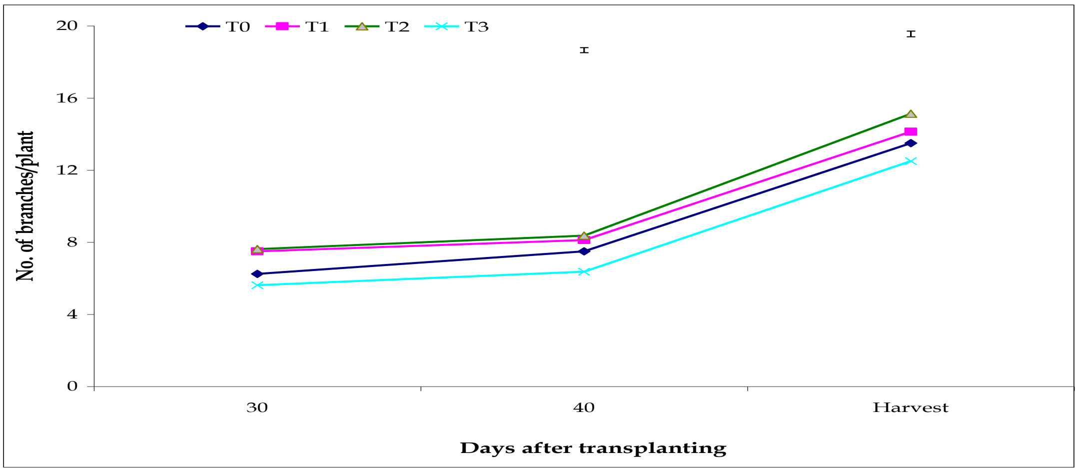
Significant difference between the varieties in the number of branches per plant was observed. The maximum number of branches per plant (14.75) was found in BARI Tomato-1 variety (V_2) whereas the minimum number of branches per plant (12.88) was found in BARI Tomato-1 variety (V_1) (Figure 5).



Here, V_1: BARI Tomato-1; V_2: BARI Tomato-2

Figure 5. Performance of different tomato varieties on number of branch per plant at different days after transplanting

In case of nitrobenzene doses significant variation was observed in the number of branches per plant (Appendix III). Maximum number of branches per plant (15.13) was found in @ 2 mL application of nitrobenzene (T_2) and minimum number of branches per plant (12.5) was found in application of nitrobenzene @ 2.5 mL (T_3) (Figure 6).



* Here, T_0: 0 mL, T_1: 1.5 mL, T_2: 2 mL, T_3: 2.5 mL

Figure 6. Effect of nitrobenzene doses on number of branches/plant at different DAT in tomato

In case of interaction effect, significant variation was observed in the number of branches per plant (Appendix III). Maximum number of branches per plant (16.25) was found in BARI Tomato-2 variety with interaction of nitrobenzene @ 2mL (V_2T_2) which was statistically similar with (V_2T_1) and minimum number of branches per plant (12.25) was found in BARI Tomato-1 variety in 2.5 mL application of growth retardant (V_1T_3) (Table 4).

Table 4. Interaction effect of different varieties and nitrobenzene doses on number of branches per plant of tomato at different days after transplanting (DAT)

Treatment combination*	No. of branches per plant at different DAT		
	30	40	Final harvest
V_1T_0	6.25 bc	6.75 de	12.50 c
V_1T_1	6.75 b	7.25 cd	12.75 c
V_1T_2	6.75 b	7.50 c	14.00 b
V_1T_3	5.50 c	6.25 e	12.25 c
V_2T_0	6.25 bc	8.25 b	14.50 b
V_2T_1	8.25 a	9.00 a	15.50a
V_2T_2	8.50a	9.25 a	16.25a
V_2T_3	5.75 c	6.50 e	12.75 c
$LSD_{0.05}$	0.845	0.688	0.777
Level of significance	**	**	**
CV (%)	8.52	6.16	3.82

*Here, V_1: BARI Tomato-1; V_2: BARI Tomato-2 and Here, T_0: 0 mL, T_1: 1.5 mL, T_2: 2 mL, T_3: 2.5 mL

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

Table 5. Effect of different varieties on yield contributing characters of tomato

Variety	Days from transplanting to flowering	No. of flower clusters per plant	No. of flowers per cluster	No. of flowers per plant	No. of fruits per cluster	No. of fruits per plant	Fruit setting (%)
V_1	45.69 a	5.71 b	7.00 b	39.12 b	4.17 b	22.69 b	60.55 a
V_2	42.09 b	6.17 a	7.19 a	43.45 a	4.46 a	25.61 a	55.72 b
$LSD_{0.05}$	1.270	0.132	0.125	0.682	0.156	0.592	0.683
Level of significance	**	**	**	**	**	**	**
CV (%)	3.93	3.01	2.39	2.25	4.94	3.33	1.60

*Here, V_1: BARI Tomato-1; V_2: BARI Tomato-2

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

4.4 Days of 1st flowering from transplanting

Flowering is the important factor in yield count in tomato. In case of varieties, days of flowering were varied significantly (Appendix IV). Maximum days of flowering required for BARI Tomato-2 variety (45.69) whereas minimum (42.09) found in BARI Tomato-2 variety (Table 4).

In case of nitrobenzene doses significant variation was observed in the days of 1st flowering from transplanting (Appendix IV). Maximum days of flowering required for (T_3) treatment (46.28) whereas minimum (41.1) found in (T_2) treatment (Table 5).

In case of interaction effect, significant variation was observed in the number of days from transplanting to flowering (Appendix IV). Maximum number of days required (47.89) in BARI Tomato-1 variety with interaction of nitrobenzene @ 2.5mL (V_1T_3) and minimum days required (39.87) in BARI Tomato -2 variety in 2 mL application of nitrobenzene (V_2T_2) (Table 6).

Table 6. Effect of growth retardant doses on yield contributing characters of tomato

Nitrobenzene doses	Days from transplanting to flowering	No. of flower clusters per plant	No. of flowers per cluster	No. of flowers per plant	No. of fruits per cluster	No. of fruits per plant	Fruit setting (%)
T_0	44.66 ab	5.91 b	7.08 ab	40.13 c	4.22 bc	23.25 c	57.95 c
T_1	43.51 b	6.09 ab	7.12 ab	42.39 b	4.40 ab	25.25 b	59.67 b
T_2	41.10 c	6.25 a	7.22 a	45.80 a	4.52 a	28.84 a	62.15 a
T_3	46.28 a	5.50 c	6.95 b	36.82 d	4.10 c	19.25 d	52.78 d
$LSD_{0.05}$	1.80	0.186	0.177	0.965	0.221	0.836	0.965
Level of significance	**	**	*	**	**	**	**
CV (%)	3.93	3.01	2.39	2.25	4.94	3.33	1.60

* Here, T_0: 0 mL, T_1: 1.5 mL, T_2: 2 mL, T_3: 2.5 mL

Table 7. Interaction effect of different varieties and nitrobenzene doses on yield contributing characters of tomato

Treatment combination	Days from transplanting to flowering	No. of flower clusters per plant	No. of flowers per cluster	No. of flowers per plant	No. of fruits per cluster	No. of fruits per plant	Fruit setting (%)
V_1T_0	46.87	5.67	6.98	38.93 e	4.10	22.75 e	58.44c
V_1T_1	45.67	5.85	7.00	40.22 de	4.25	24.75 cd	61.54b
V_1T_2	42.33	6.00	7.12	42.67 c	4.33	26.00 b	60.93b
V_1T_3	47.89	5.33	6.91	34.67 f	4.00	17.25 g	61.29b
V_2T_0	42.45	6.15	7.19	41.33 cd	4.34	23.75de	57.46c
V_2T_1	41.36	6.33	7.25	44.55 b	4.56	25.75 bc	57.80c
V_2T_2	39.87	6.51	7.33	48.93 a	4.72	31.69 a	63.36a
V_2T_3	44.67	5.68	7.00	38.97 e	4.20	21.25 f	44.26d
$LSD_{0.05}$	2.54	0.263	0.250	0.136	0.312	1.18	1.37
Level of significance	NS	NS	NS	**	NS	**	**
CV (%)	3.93	3.01	2.39	2.25	4.94	3.33	1.60

** = Significant at 1% level of probability, NS = Not significant
V_1 = BARI tomato -1, V_2 = BARI tomato -2; T_0 =0 mL, T_1 = 1.5 mL, T_2 = 2 mL, T_3 = 2.5 mL

4.5. Number of flower clusters per plant

In case of different tomato varieties the number of flower cluster per plant (Appendix IV, Table-4). Maximum number of flower cluster (6.17) was found in BARI Tomato-2 (V_2) variety and minimum number of flower clusters (5.71) was found in BARI Tomato-1 (V_1) variety. Similar results were reported by Sk. Rahul *et al.* (2017) Significant difference among the tomato varieties incase of the number of flower clusters per plant.

In case of different nitrobenzene doses, the number of flower clusters per plant varied significantly (Appendix IV). Maximum number of flower clusters per plant (6.25) was found in 2 mL application of nitrobenzene (T_2) and minimum number of flower clusters (5.5) were found in 2.5 mL application of growth retardant doses (T_3) (Table 5).

In case of combination treatment the number of flower cluster per plant found in (Appendix IV). Maximum number of flower cluster (6.51) was found in BARI Tomato -2 variety @ 2mL application of nitrobenzene (V_2T_2) and minimum number of flower clusters (5.33) was found in BARI Tomato -1 variety @ 2.5 mL application of nitrobenzene doses (V_1T_3) (Table 6).

4.6. Number of flower per cluster

In case of tomato varieties, number of flower /cluster found in (Appendix IV). Maximum number of flower per cluster (7.19) was found in BARI Tomato-2 (V_2) variety and minimum number of flower per cluster (7.0) were found in BARI Tomato-1 (V_1) variety (Table 4). The genotypic differences for number of flower per cluster were also observed by Muniappan *et al* (2010) and Islam and Uddin (2009) in brinjal.

In case of different nitrobenzene doses the number of flower per cluster found in (Appendix IV). Maximum number of flower per cluster (7.22) was found in 2 mL application of nitrobenzene (T_2) and minimum number of flower per cluster (6.95) was found in 2.5 mL application of nitrobenzene doses (T_3) (Table 5).

In case of combination treatment the number of flower cluster per plant found in (Appendix IV). Maximum number of flower per cluster (7.33) was found in BARI Tomato-2 variety @ 2mL application of nitrobenzene (V_2T_2) and minimum number of flower per clusters (6.91) was found in BARI Tomato -1 variety @ 2.5 mL application of nitrobenzene doses (V_1T_3) (Table 6).

4.7 Number of flower per plant

In case of tomato varieties, number of flower/cluster found in (Appendix IV). Maximum number of flower per plant (43.45) was found in BARI Tomato-2 (V_2) variety and minimum number of flower (39.12) were found in BARI Tomato-1 (V_1) variety (Table 4).

In case of different nitrobenzene doses the number of flower per cluster found in (Appendix IV). Maximum number of flower per plant (45.8) was found in 2mL application of nitrobenzene (T_2) and minimum number of flower per plant (36.82) was found in 2.5 mL application of nitrobenzene doses (T_3) (Table 5).

In case of combination treatment the number of flower cluster per plant found in (Appendix IV). Maximum number of flower per plant (48.93) was found in BARI Tomato -2 variety @ 2mL application of nitrobenzene (V_2T_2) and minimum number of flower per plant (34.67) was found in BARI Tomato -1 variety @ 2.5 mL application of nitrobenzene doses (V_1T_3) (Table 6).

4.8 Number of fruit per cluster

In case of tomato varieties, number of fruit/cluster found in (Appendix IV). Maximum number of fruit per cluster (4.46) was found in BARI Tomato-2 (V_2) variety and minimum numbers of fruit per clusters (4.17) were found in BARI Tomato-1 (V_1) variety (Table 4).

In case of different nitrobenzene doses the number of fruit per cluster found in (Appendix IV). Maximum number of fruit per cluster (4.52) was found in 2 mL application of nitrobenzene (T_2) and minimum number of fruit per cluster (4.1) was found in 2.5 mL application of nitrobenzene doses (T_3) (Table 5).

In case of combination treatment the number of fruit per cluster found in (Appendix IV). Maximum number of fruit per cluster (4.72) was found in BARI Tomato-2 variety @ 2mL application of nitrobenzene (V_2T_2) and minimum number of fruit per cluster (4.0) was found in BARI Tomato-1 variety @ 2.5 mL application of nitrobenzene doses (V_1T_3) (Table 6).

4.9 Number of fruit per plant

In case of tomato varieties, number of fruit/plant found in (Appendix IV). Maximum number of fruit per plant (25.61) was found in BARI Tomato-2 (V_2) variety and minimum numbers of fruit per plant (22.69) were found in BARI Tomato-1 (V_1) variety (Table 4).

In case of different nitrobenzene doses the number of fruit per plant found in (Appendix IV). Maximum number of fruit per plant (28.84) was found in 2mL application of nitrobenzene (T_2) and minimum number of fruit per plant (19.25) was found in 2.5mL application of nitrobenzene doses (T_3) (Table 5).

In case of combination treatment the number of fruit per plant found in (Appendix IV). Maximum number of fruit per plant (31.69) was found in BARI Tomato -2 variety @ 2mL application of nitrobenzene (V_2T_2) and minimum number of fruit per plant (17.25) was found in BARI Tomato -1 variety @ 2.5 mL application of nitrobenzene doses (V_1T_3) (Table 6).

4.10 Fruit length

Significant difference was revealed on fruit length (cm) with different tomato varieties (Appendix V, Table-7). Among the varieties of tomato V_2 (BARI Tomato-2) gave the longest fruit (7.27 cm) while V_1 (BARI Tomato-1) gave the shortest fruit (6.22 cm) length. This is may be due to variation of varietal characteristics. Hossain (2001), Singh and Sahu (1998) also reported varietal influence on the length of fruit

Significant variation was found for fruit length (cm) in case of different nitrobenzene doses. Maximum fruit length (7.13 cm) was observed in (T_2) treatment and minimum fruit length (6.32 cm) was observed in (T_3) (Table 8). Chapagain *et al.* (2011) reported largest fruit size in US-04 with a diameter of 5.7 cm.

Table 8. Effect of different varieties on the yield of tomato

Growth retardant doses	Length of fruit (cm)	Diameter of fruit (cm)	Dry matter content in plant (%)	Weight of individual fruit (g)	Fruit yield/plot (kg)
T_0	6.65 c	3.82 c	3.23 c	163.65 c	34.28 c
T_1	6.88 b	4.13 b	3.35 b	168.08 b	38.22 b
T_2	7.13 a	4.27 a	3.75 a	176.26 a	45.94 a
T_3	6.32 d	3.50 d	3.18 c	150.22 d	26.11 d
$LSD_{0.05}$	0.161	0.104	0.057	2.42	1.47
Level of significance	**	**	**	**	**
CV (%)	2.27	2.50	1.50	1.42	3.92

Here, V_1: BARI Tomato-1; V_2: BARI Tomato-2

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

Significant variation was found for fruit length (cm) in case of combined effect. Maximum fruit length (7.59 cm) was found in BARI Tomato-2 variety @ 2mL application of nitrobenzene doses (V_2T_2) and minimum fruit length (5.75 cm) was found in BARI Tomato-1 variety @ 2.5 mL application of nitrobenzene (V_1T_3) (Table 9).

Table 9. Effect of nitrobenzene doses on the yield of tomato

Nitrobenzene doses	Length of fruit (cm)	Diameter of fruit (cm)	Dry matter content in plant (%)	Weight of individual fruit (g)	Fruit yield/plot (kg)
T_0	6.65 c	3.82 c	3.23 c	163.65 c	34.28 c
T_1	6.88 b	4.13 b	3.35 b	168.08 b	38.22 b
T_2	7.13 a	4.27 a	3.75 a	176.26 a	45.94 a
T_3	6.32 d	3.50 d	3.18 c	150.22 d	26.11 d
$LSD_{0.05}$	0.161	0.104	0.057	2.42	1.47
Level of significance	**	**	**	**	**
CV (%)	2.27	2.50	1.50	1.42	3.92

T_0 =0 mL, T_1 = 1.5 mL, T_2 = 2 mL, T_3 = 2.5 mL

4.11 Fruit diameter (cm)

Significant difference was revealed on fruit diameter (cm) with different tomato varieties (Appendix V). Among the varieties of tomato V_2 (BARI Tomato-2) gave the maximum fruit (4.26 cm) while V_1 (BARI Tomato-1) gave the minimum fruit diameter (3.62 cm) (Table 7). Muniappan *et al* (2010) reported wide range of variability in case of fruit diameter.

Significant variation was found for fruit diameter (cm) in case of different growth retardant doses. Maximum fruit diameter (4.27 cm) was observed in (T_2) treatment and minimum fruit diameter (3.18 cm) was observed in (T_3) which was statistically similar with T_0 treatment (Table 8). Chapagain *et al.* (2011) reported largest fruit size in US-04 with a diameter of 5.7 cm.

Significant variation was found for fruit length (cm) in case of combined effect. Maximum fruit diameter (4.64 cm) was found in BARI Tomato-2 variety @ 2mL application of nitrobenzene doses (V_2T_2) which was statistically similar with (V_2T_1) treatment and minimum fruit diameter (3.32 cm) was found in BARI Tomato-1 variety @ 2.5 mL application of nitrobenzene (V_1T_3) (Table 10).

Table 10. Interaction effect of different varieties and nitrobenzene doses on the yield of tomato

Treatment	Length of fruit (cm)	Diameter of fruit (cm)	Dry matter content in plant (%)	Weight of individual fruit (g)	Fruit yield/plot (kg)
V_1T_0	6.11	3.50 e	3.31 d	157.32 d	32.21 d
V_1T_1	6.33	3.76 cd	3.55 c	165.43 c	36.86 c
V_1T_2	6.67	3.90 c	3.65 b	169.55 b	39.69 b
V_1T_3	5.75	3.32 f	3.18 e	144.75 e	22.45 f
V_2T_0	7.19	4.15 b	3.15 e	169.98 b	36.34 c
V_2T_1	7.43	4.50 a	3.15 e	170.74 b	39.58 b
V_2T_2	7.59	4.64 a	3.86 a	182.96 a	52.18 a
V_2T_3	6.89	3.69d	3.19 e	155.68 d	29.77 e
$LSD_{0.05}$	0.227	0.147	0.080	3.42	2.09
Level of significance	NS	**	**	**	**
CV (%)	2.27	2.50	1.50	1.42	3.92

** = Significant at 1% level of probability, NS = Not significant
V_1 = BARI tomato -1, V_2 = BARI tomato -2; T_0 =0 mL, T_1 = 1.5 mL, T_2 = 2 mL, T_3 = 2.5 mL

4.12. Dry matter content in plant (%)

Significant difference was revealed on dry matter content in plant (%) with different tomato varieties (Appendix V). Among the varieties of tomato V_2 (BARI Tomato-2) gave the minimum dry matter content in plant (3.34%) while V_1 (BARI Tomato-1) gave the maximum dry matter content in plant (3.42 cm) (Table 7).

Significant variation was found in dry matter content in plant (%) in case of different nitrobenzene doses. Maximum plant dry matter content (3.75 %) was observed in (T_2) treatment and minimum plant dry matter content (3.18 %) was observed in (T_3) which was statistically similar with T_0 treatment (Table 8).

Significant variation was found for dry matter content in plant (%) in case of combined effect. Maximum dry matter content in plant (3.86%) was found in BARI Tomato -2 variety @ 2mL application of nitrobenzene doses (V_2T_2) and minimum dry matter content (3.32 mm) was found in (V_2T_0) and (V_2T_1) which were statistically similar with V_1T_3 and V_2T_3 (Table 9).

4.13 Fresh fruit weight (g)

Single fruit weight showed significant variation among the tomato varieties (Appendix V) Maximum weight/ fruit (169.84 g) was found in BARI Tomato-2 (V_2) variety and minimum weight/fruit (159.26 g) was found in BARI Tomato-1 (V_1) variety (Table 7). Variation in single fruit weight was also observed by Glavinich *et al.,* (1982), Gabal *et al.,* (1985), Bhangu and Singh (1993), Mehraj *et al.,* (2014) and Islam (2014).

In case of different nitrobenzene doses, the number individual fruit weight found in (Appendix V). Maximum weight/fruit (176.26 g) was found in 2 mL application of nitrobenzene (T_2) and minimum fruit weight (150.22 g) was found in 2.5 mL application of nitrobenzene doses (T_3) (Table 8).

In case of combination treatment, the number of single fruit weight varied significantly (Appendix V). Maximum weight/fruit (182.96 g) was found BARI Tomato-2 variety and dose of nitrobenzene @ 2mL (V_2T_2) and minimum weight/fruit (144.75 g) was found in BARI Tomato-1 variety and 2.5 mL of nitrobenzene dose in tomato (V_1T_3) (Table 9).

4.14 Fruit yield per plot (kg)

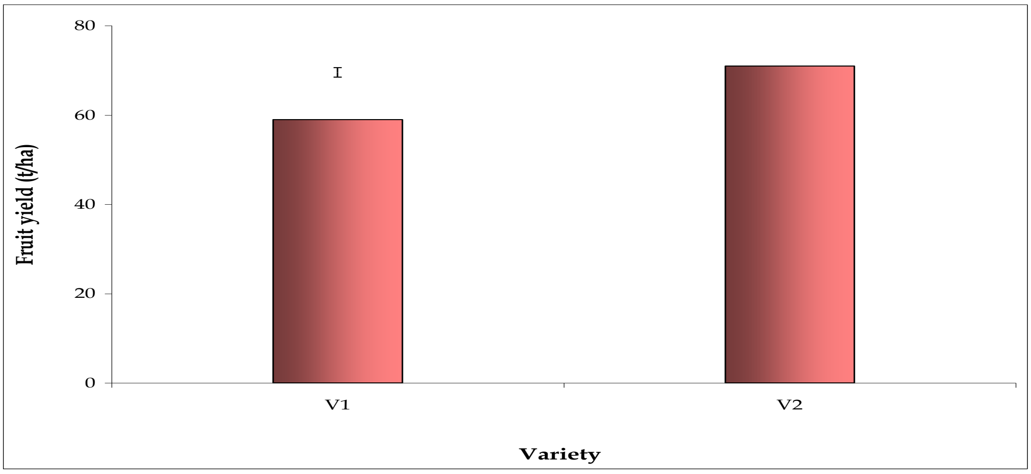
It was observed that the tomato varieties showed significant variation from yield per plot (kg) (Appendix V). Maximum yield per plot (39.47 kg) was found from BARI Tomato-2 variety while minimum (32.80 kg) from BARI Tomato-1 (V_1) variety (Table 7). The variations of yield may also depend on genetic differences among the varieties, since they were grown under the same environmental conditions. The observations of Hossain (2001), Tika *et al.* (2011), Mishra and Lal (1998) and Rida *et* *al*., (2002) also confirms the presented findings too. Mehraj *et al.* (2014) also observed that yield per plant varied significantly among the tomato varieties.

In case of different nitrobenzene doses yield/plot (kg) found in (Appendix V). Maximum yield/plot (45.94 kg) was found in 2 mL dose of nitrobenzene (T_2) and minimum yield/plot (26.11kg) was found in 2.5 mL dose of nitrobenzene doses (T_3) (Table 8).

In case of combination treatment yield/plot (kg) varied significantly (Appendix V). Maximum yield/plot (52.18 kg) was found BARI Tomato-2 variety and application of nitrobenzene @ 2mL (V_2T_2) and minimum yield/plot (22.45 kg) was found in BARI Tomato-1 variety and 2.5 mL of nitrobenzene application in tomato (V_1T_3) (Table 9).

4.15 Yield/ha (ton)

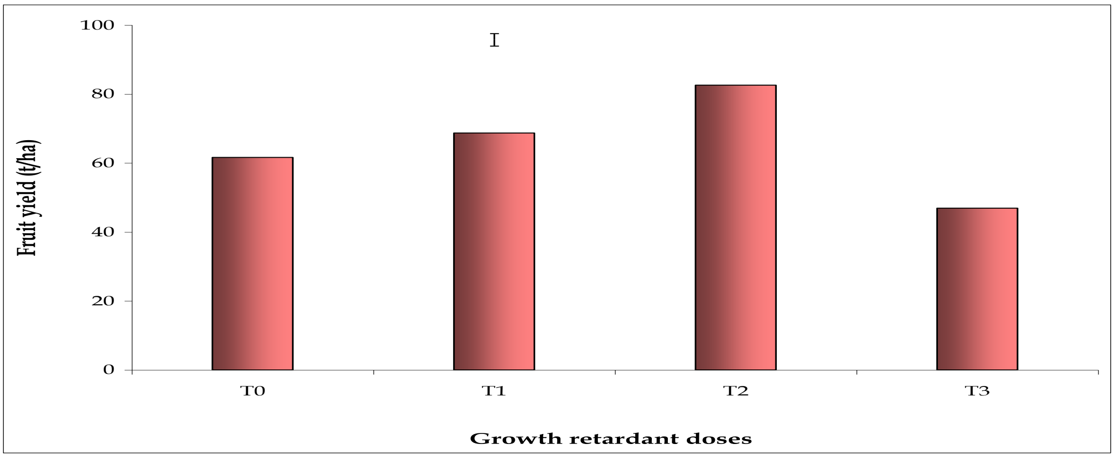
Significant differences among the tomato varieties respect to yield were highly variation (Appendix V). The highest fruit yield per hectare (70.98t) was found from BARI Tomato-2 variety (V_2). The lowest (59.0 t) was significantly obtained from BARI Tomato-1 (V_1) (Fig. 7). This may be due to the inherent ability of the hybrids and their better response to controlled environment condition. Similar reports of better performance of hybrids due to genetic makeup have been reported by Kumar (2014), Singh *et al*. (2001), Pandey *et al.* (2006), Arora *et al*. (2007).



Here, V_1: BARI Tomato-1; V_2: BARI Tomato-2

Figure. 7. Effect of different varieties on yield per hectare in tomato

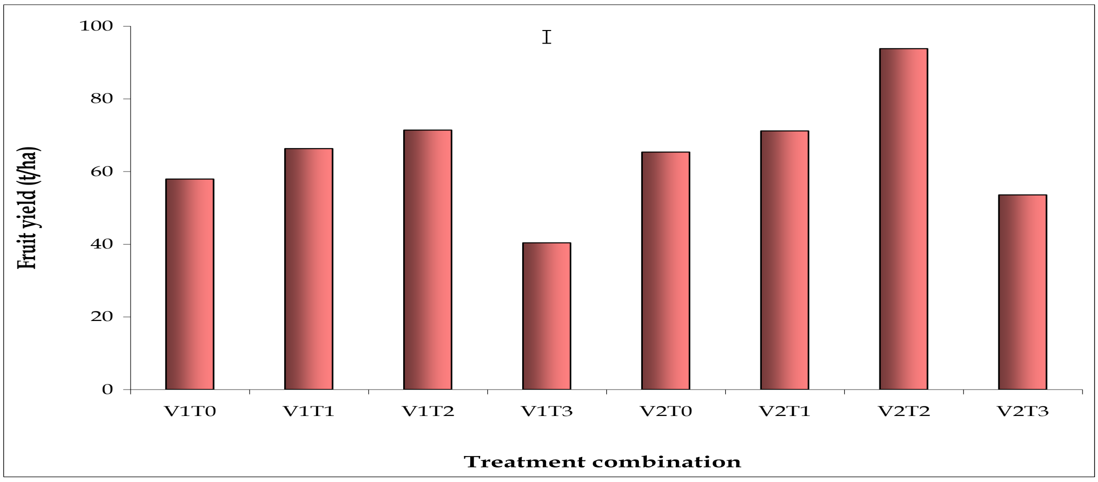
In case of different nitrobenzene doses yield/plot (kg) varied significantly (Appendix V). Maximum yield/plot (82.62 t) was found in 2 mL application of nitrobenzene (T_2) and minimum yield/plot (46.96 t) was found in 2.5 mL application of nitrobenzene doses (T_3) (Fig. 8).



Here, T_0 =0 mL, T_1 = 1.5 mL, T_2 = 2 mL, T_3 = 2.5 mL

Figure 8. Effect of growth retardant nitrobenzene doses on yield per hectare in tomato

In case of combined effect of tomato varieties and nitrobenzene doses, significant variation was found in fruit yield per hectare (t). Maximum fruit yield per hectare (93.85 t) was obtained from BARI Tomato-2 variety with 2 mL application of nitrobenzene doses (V_2T_2) whereas minimum fruit yield per hectare (40.4 t) was obtained from BARI Tomato-1 variety with 2.5 mL application of nitrobenzene doses (V_1T_3) (Fig.9).



V_1 = BARI tomato -1, V_2 = BARI tomato -2;T_0 =0 mL, T_1 = 1.5 mL, T_2 = 2 mL, T_3 = 2.5 mL

Figure 9. Combined effects of different varieties and nitrobenzene doses on yield per hectare in tomato

4.16 Minerals content (%)

Significant difference was revealed on minerals content with different tomato varieties (Appendix VI). Among them BARI Tomato-2 variety showed the maximum nutrient K, Na, Ca and P content percentage 1.99 %, 0.099 %, 0.05 % and 0.509% respectively whereas, BARI Tomato-1 variety showed the minimum nutrient content (K :1.15 %, Na: 0.084 %, Ca: 0.05 % and P: 0.475 %) (Table 11).

Table 11. Effect of different varieties on mineral content of tomato

Variety	% K	% Na	%Ca	% P
V_1	1.15 b	0.084 b	0.049	0.475 b
V_2	1.99 a	0.099 a	0.050	0.509 a
$LSD_{0.05}$	0.040	0.004	0.005	0.010
Level of significance	**	**	NS	**
CV (%)	3.38	6.43	12.69	2.69

Here, V_1: BARI Tomato-1; V_2: BARI Tomato-2

Significant difference was revealed on nutrient content with nitrobenzene doses (Appendix VI). Among them T_2 treatment showed the maximum nutrient K, Na, Ca and P content percentage 2.05 %, 0.11 %, 0.058 % and 0.542% respectively whereas, T_3 showed the minimum nutrient content (K :1.3 %, Na: 0.076 %, Ca: 0.033 % and P: 0.447 %) (Table 12).

Table 12. Effect of nitrobenzene doses on mineral content of tomato

Growth retardant doses	% K	% Na	%Ca	% P
T_0	1.45 b	0.084 c	0.048 b	0.474 c
T_1	1.46 b	0.096 b	0.060 a	0.505 b
T_2	2.05 a	0.110 a	0.058 a	0.542 a
T_3	1.30 c	0.076 d	0.033 c	0.447 d
$LSD_{0.05}$	0.057	0.0061	0.0065	0.013
Level of significance	**	**	**	**
CV (%)	3.38	6.43	12.69	2.69

Here, T_0 =0 mL, T_1 = 1.5 mL, T_2 = 2 mL, T_3 = 2.5 mL

In case of combined effect of tomato varieties and nitrobenzene doses, significant variation was found in mineral content (%) tomato (Appendix VI). Among them V_2T_2 treatment showed the maximum nutrient K, Na, and P content percentage 2.47 %, 0.12 %, and 0.568 % respectively and maximum (0.065%) Ca content found in (V_2T_1) treatment whereas, V_1T_3 showed the minimum nutrient content (K: 0.95%, Na: 0.07%, Ca: 0.03 % and P: 0.421 %) (Table 13).

Table 13. Interaction effect of different varieties and nitrobenzene doses on mineral content (%) of tomato

Treatment combination	% K	% Na	%Ca	% P
V_1T_0	1.00 d	0.075	0.055 b	0.474 c
V_1T_1	1.00 d	0.090	0.055 b	0.490 c
V_1T_2	1.63 c	0.100	0.055 ab	0.517 b
V_1T_3	0.95 d	0.070	0.030 d	0.421 d
V_2T_0	1.90 b	0.093	0.040 c	0.475 c
V_2T_1	1.92 b	0.102	0.065 a	0.521 b
V_2T_2	2.47 a	0.120	0.060 ab	0.568 a
V_2T_3	1.66 c	0.081	0.035 cd	0.473 c
$LSD_{0.05}$	0.080	0.0087	0.0092	0.019
Level of significance	**	NS	**	**
CV (%)	3.38	6.43	12.69	2.69

** = Significant at 1% level of probability, NS = Not significant

V_1 = BARI tomato -1, V_2 = BARI tomato -2; T_0 =0 mL, T_1 = 1.5 mL, T_2 = 2 mL, T_3 = 2.5 mL

CHAPTER V

SUMMARY AND CONCLUSION

Summary

In order to study the effect of nitrobenzene on growth, yield and minerals content of tomato at Sher-e-Bangla Agricultural University, Dhaka during period from November, 2017 to April, 2018. Two factorial experiment included tomato varieties viz. V_1 (BARI Tomato-1) and V_2 (BARI Tomato-2) and Plant Growth Retardant nitrobenzene doses (4Doses): 0 mL, 1.5 mL, 2 mL, 2.5 mL were outlined in Completely Randomized Block Design (RCBD) with four replications.

Collected data were statistically analyzed for the evaluation of treatments and variety. The findings have been described in the following –

The highest plant height was found from V_1 T_0 (97.50 cm) whereas the shortest from V_1 T_3 (76.00 cm) at harvesting time. In case of variety, the maximum number of leaves (62.5) was found from V_2 and minimum (53.19) from V_1 at harvest time. And in case of treatment, the maximum number of leaves (65.25) was found from T_2 and minimum from T_3 (48.38) at harvest time. In case of combined effect, maximum number of leaves (72.75) was found from V_2T_2 and minimum (46.0) from V_1T_3 at harvest time. Maximum number of branch (14.75) was observed in V_2 and than the variety V_1 (3.67). In case of nitrobenzene treatment, maximum number of branch (15.13) was found in T_2 and minimum (12.5) in T_3. Combined effect of variety and nitrobenzene, maximum number of branch (16.25) was found in V_2T_2 and minimum (12.25) in V_1T_3.

Maximum number of flower cluster per plant (6.17) was found in V_2 and minimum (5.71) in V_1. In case of nitrobenzene treatment, maximum number of flower cluster per plant (6.25) was found in T_2 and minimum (5.5) in T_3. Combined effect of variety and nitrobenzene doses, maximum flower cluster per plant (6.51) was found in V_2T_2 and minimum (5.33) in V_1T_3. Maximum number flower per cluster (7.19) was found in V_2 and minimum (7.0) in V_1. In case of nitrobenzene treatment, maximum number

of flower per cluster (7.22) was found in T_2 and minimum (6.95) in T_3. Combined effect of variety and nitrobenzene doses, maximum flower per cluster (7.33) was found in V_2T_2 and minimum (6.91) in V_1T_3. Maximum number flower per plant (43.45) was found in V_2 and minimum (39.12) in V_1. In case of nitrobenzene treatment, maximum number of flower per plant (45.8) was found in T_2 and minimum (36.82) in T_3. Combined effect of variety and nitrobenzene doses, maximum flower per plant (48.97) was found in V_2T_2 and minimum (34.67) in V_1T_3.

Maximum number of fruit per cluster (4.46) was found in V_2 and minimum (4.17) in V_1. In case of nitrobenzene treatment, maximum number of fruit per cluster (4.52) was found in T_2 and minimum (4.1) in T_3. Combined effect of variety and nitrobenzene doses, maximum fruit per cluster (4.72) was found in V_2T_2 and minimum (4.0) in V_1T_3. Maximum number of fruit per plant (25.61) was found in V_2 and minimum (22.69) in V_1. In case of nitrobenzene treatment, maximum number of fruit per plant (28.84) was found in T_2 and minimum (19.25) in T_3. Combined effect of variety and nitrobenzene doses, maximum fruit per plant (31.69) was found in V_2T_2 and minimum (17.25) in V_1T_3.Maximum fruit length (7.27 cm) was found in V_2 and minimum (6.22 cm) in V_1. In case of nitrobenzene treatment, maximum fruit length (7.13 cm) was found in T_2 and minimum (6.32 cm) in T_3. Combined effect of variety and nitrobenzene doses, maximum fruit length (7.59 cm) was found in V_2T_2 and minimum (5.75 cm) in V_1T_3.Maximum fruit diameter (4.26 mm) was found in V_2 and minimum (3.62 mm) in V_1. In case of nitrobenzene treatment, maximum fruit diameter (4.27 mm) was found in T_2 and minimum (3.18 mm) in T_3. Combined effect of variety and nitrobenzene doses, maximum fruit diameter (4.64 mm) was found in V_2T_2 and minimum (3.32 mm) in V_1T_3.Highest dry matter content in plant (3.42%) was found in V_2 and minimum (3.34%) in V_1. In case of nitrobenzene treatment, highest dry matter content in plant (3.75%) was found in T_2 and minimum (3.18%) in T_3. Combined effect of variety and nitrobenzene doses, dry matter content in plant (3.86%) was found in V_2T_2 and minimum (3.32 mm) in V_2T_0. Maximum single fruit weight (169.84 g) was observed in V_2 and minimum (159.26g) in V_1. In case of nitrobenzene treatment, maximum single fruit weight (176.26 g) was observed in T_2 and minimum (150.22g) in $T_{3.}$ Combined effect of variety and nitrobenzene doses, maximum single fruit weight (182.96 g) was observed in V_2T_2 and minimum (144.75g) in V_1T_3.

Considering variety, maximum yield per plot (39.47 kg) was observed in V_2 and minimum (32.8 kg) in V_1. In case of nitrobenzene treatment, maximum fruit yield per plot (45.94 kg) was observed in T_2 and minimum (26.11 kg) in $T_{3.}$Combined effect of variety and nitrobenzene doses, maximum fruit yield per plot (52.18 kg) was observed in V_2T_2 and minimum (22.45 kg) in V_1T_3. Considering variety, maximum yield per hectare (70.98 t) was observed in V_2 and minimum (59.0 t) in V_1. In case of nitrobenzene treatment, maximum yield per hectare (82.62 t) was observed in T_2 and minimum (46.96 t) in $T_{3.}$ Combined effect of variety and nitrobenzene doses, maximum fruit yield per hectare (93.85 t) was observed in V_2T_2 and minimum (40.4) in V_1T_3.

Considering variety, maximum mineral (K, Na, Ca and P) content (1.99%, 0.099%, 0.055% and 0.509%) was observed in V_2 and minimum (1.15%, 0.084%, 0.049% and 0.475%) in V_1. In case of nitrobenzene treatment, maximum mineral (K, Na, Ca and P) content (2.05%, 0.11%, 0.058% and 0.542%) was observed in T_2 and minimum (1.3%, 0.076%, 0.033% and 0.447%) in $T_{3.}$ Combined effect of variety and nitrobenzene doses, mineral (K, Na, and P) content (2.47%, 0.12% and 0.521%) was observed in V_2T_2 and Ca content in V_2T_1 where minimum (0.95%, 0.07%, 0.03% and 0.421%) in V_1T_3.

Conclusion

In respect of the above results, variety V_2 (BARI Tomato-2) showed maximum leaves number, maximum branch number, days of 1^{st} flowering from transplanting, flower per cluster, flower per plant, fruit per cluster, fruit per plant, single fruit weight, fruit yield per plot, yield per hectare and nutrient content. On the other hand, 2mL dose of nitrobenzene application performed excellent among the nitro benzene treatment applied in terms of all parameters. Besides the combination, variety (BARI Tomato-2) treated with 2mL dose of nitrobenzene performed as the best combination. Regarding correlation studies, it can be easily stated that branch number, flower cluster per plant,

plant height and days to flowering was significantly positively correlated with all of yield. In case of nitrobenzene treatment for mineral nutrients, maximum mineral (Na, K, P) found in (T_2) treatment and Ca found in (T_1) where minimum found in (T_3). Combined effect of variety and nitrobenzene doses, highest minerals content was found in (V_2T_2). To sum up, it can be said, combination treatment of variety BARI Tomato-2 and 2mL dose of nitrobenzene (V_2T_2) was the best for growth, yield and quality attributes of tomato. These results might be helpful for further research to establish a new growth retardant in tomato.

Recommendations

Considering the situation of the present experiment, the following suggestions may be made for further studies on plant growth regulators in tomato:

- There are number of commercial formulations of plant growth retardants which need to be tested at different concentrations.
- It is necessary to screen large number of commercial plant growth retardants than pure chemicals.
- There is a need to study the source-sink relationship by using radio labeled carbon.
- More number of plant growth regulators may be included for physiological investigations for boosting the productivity of tomato.
- Biochemical profiling of proline, sugar and nitrate reductate activity may also be included in further study for more detailed information about the precise role of plant growth retardantrs in growth and development of tomato.

CHAPTER VI

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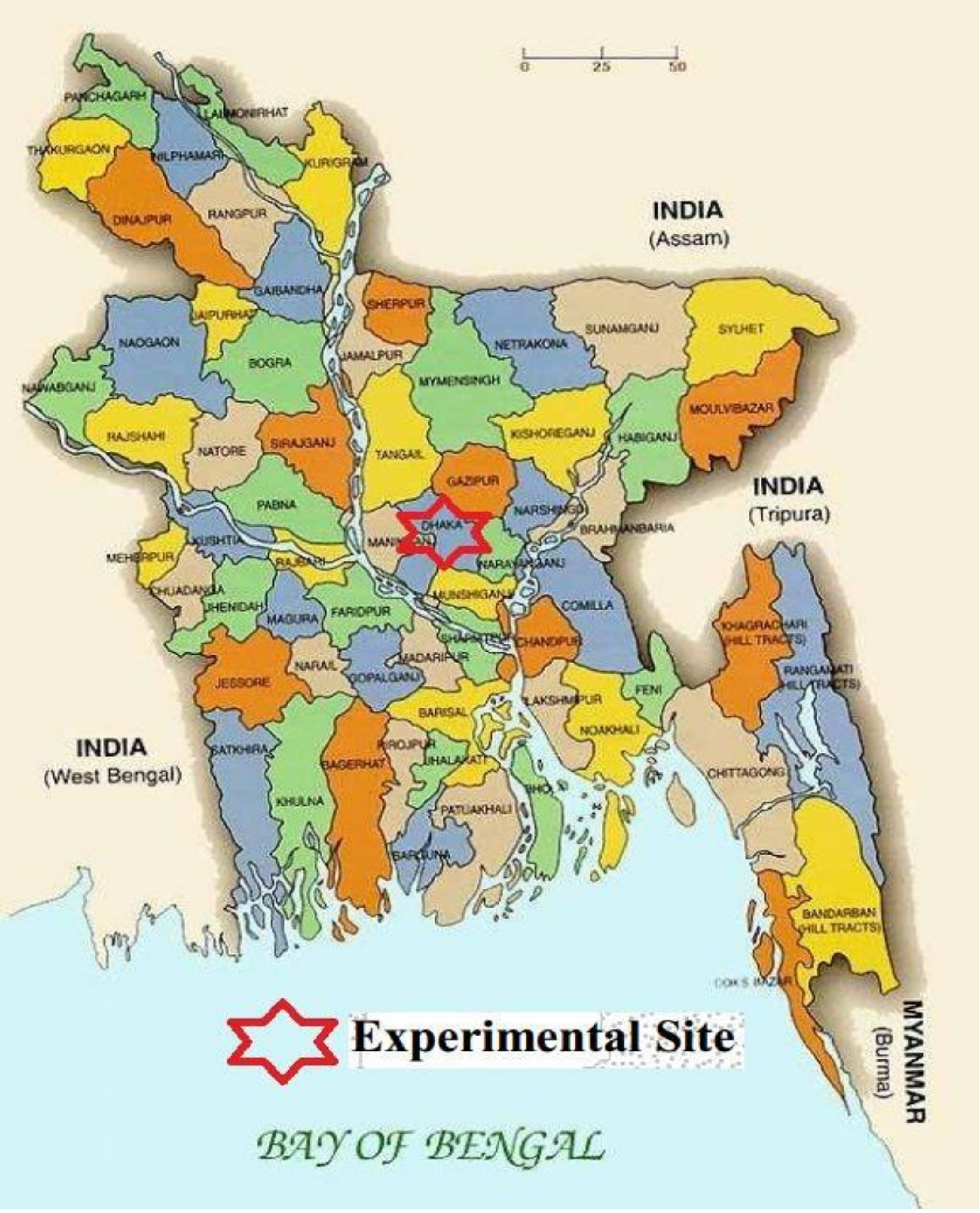
APPENDICES

Appendix I: Experimental site at Sher-e-Bangla Agricultural University, Dhaka-1207



The map of Bangladesh showing experimental site

Appendix II:

A. Morphological characteristics of soil of the experimental plot

Morphological features	Characteristics
Location	Research Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow Red Brown Terrace Soil
Land Type	Medium high land
Soil Series	Tejgaon fairly leveled
Topography	Fairly level
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	30
Textural class	Silty Clay
pH	5.8- 6.5
Organic matter (%)	1.13
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	23

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

Appendix III. Analysis of variance (mean square) of the data for yield contributing characters of tomato

Source of variation	df	Days from transplanting to flowering	No. of flower clusters per plant	No. of flowers per cluster	No. of flowers per plant	No. of fruits per cluster	No. of fruits per plant	Fruit setting (%)
Replication	3	4.610	0.053	0.038	0.973	0.054	1.458	1.650
Variety (A)	1	103.752**	1.656**	0.289**	149.47**	0.650**	68.29**	186.631**
Growth retardant doses (B)	3	37.936**	0.832**	0.100*	114.30**	0.286**	128.16**	125.867**

** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant

Appendix IV. Analysis of variance (mean square) of the data for plant height of tomato at different days after transplanting (DAT)

Source of variation	df	Plant height (cm) at different DAT			
		20	30	40	Final harvest
Replication	3	8.728	6.693	2.698	12.984
Variety (A)	1	279.661**	213.676**	693.781**	935.281**
Growth retardant doses (B)	3	59.261**	98.146**	119.281**	169.948**
A x B	3	2.461NS	3.002NS	14.365*	16.948*
Error	21	4.337	3.842	4.293	4.770

** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant

Appendix V. Analysis of variance (mean square) of the data for number of branches per plant of tomato at different days after transplanting (DAT)

Source of variation	df	No. of branches per plant at different DAT		
		30	40	Final harvest
Replication	3	0.021	0.580	0.074
Variety (A)	1	6.125**	13.781**	28.125**
Growth retardant doses (B)	3	7.583**	6.365**	9.708**
A x B	3	1.542**	1.031**	1.875**
Error	21	0.330	0.219	0.279

** = Significant at 1% level of probability

Appendix VI. Analysis of variance (mean square) of the data for number of leaves per plant of tomato at different days after transplanting (DAT)

Source of variation	df	No. of leaves per plant at different DAT		
		30	40	Final harvest
Replication	3	0.250	0.751	8.125
Variety (A)	1	1.125NS	83.851**	666.125**
Growth retardant doses (B)	3	34.250**	70.451**	424.875**
A x B	3	0.208NS	7.135**	37.042**
Error	21	1.250	0.708	8.077

** = Significant at 1% level of probability, NS = Not significant

Appendix VII. Analysis of variance (mean square) of the data for yield contributing characters of tomato

Source of variation	df	Length of fruit (cm)	Diameter of fruit (cm)	Dry matter content in plant (%)	Weight of individual fruit (g)	Fruit yield/plot (kg)	Fruit yield (t/ha)
Replication	3	0.034	0.022	0.001	5.653	4.044	13.060
Variety (A)	1	9.031**	3.125**	0.058**	895.174**	354.778**	1148.163**
Growth retardant doses (B)	3	0.938**	0.915**	0.539**	948.666**	544.801**	1761.816**
A x B	3	0.020NS	0.064**	0.134**	26.797**	37.568**	121.511**
Error	21	0.024	0.010	0.003	5.422	2.007	6.493

** = Significant at 1% level of probability, NS = Not significant

Appendix VIII: List of Plates

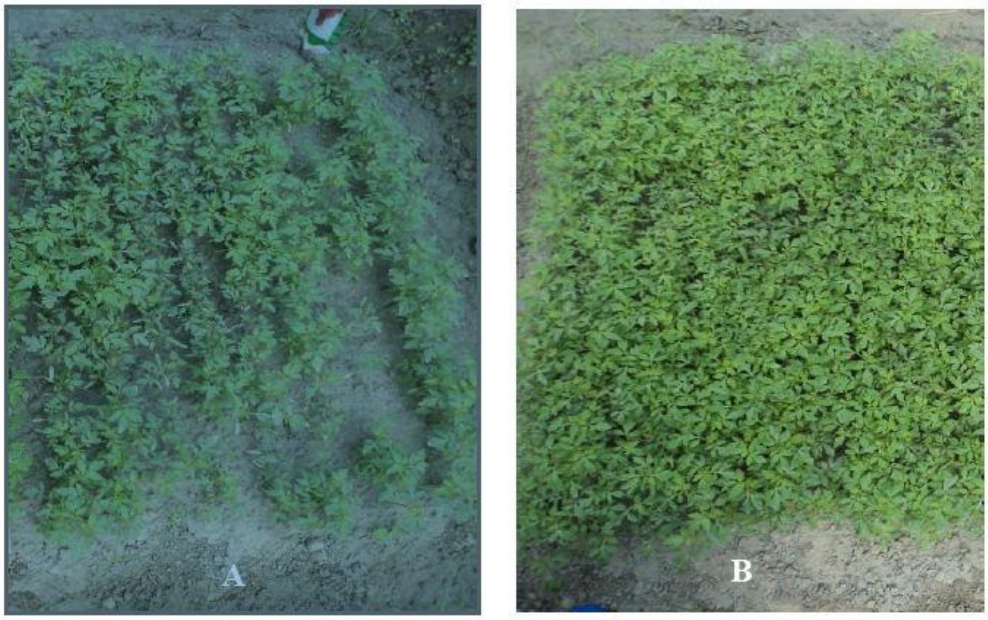


Plate 1. Photograph showing tomato seedlings; A: BARI Tomato-1 and B: BARI Tomato-2

Plate 2. Photograph showing experimental plot

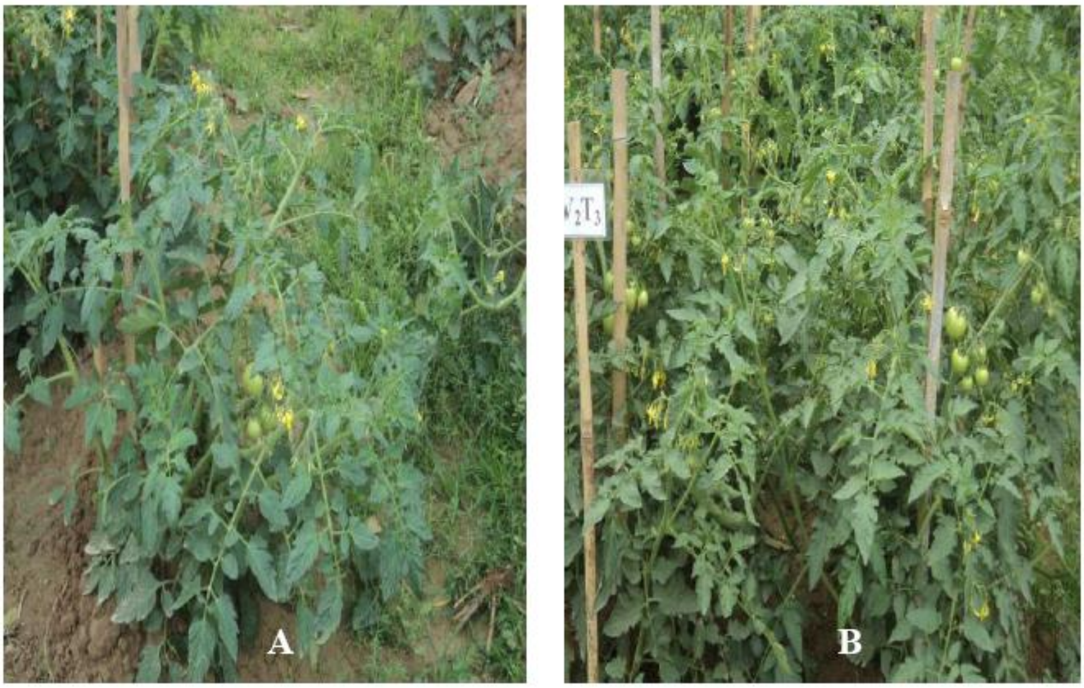


Plate 3. Photograph showing green tomato; A: BARI Tomato-1 and B: BARI Tomato-2

Plate 4. Photograph showing ripen tomato; A: BARI Tomato-1 and B: BARI Tomato-2