EFFECT OF NITROGEN AND BORON ON GROWTH AND YIELD OF BARI Tomato-18

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CERTIFICATE

This is to certify that thesis entitled, **“EFFECT OF NITROGEN AND BORON ON GROWTH AND YIELD OF BARI Tomato-18”** submitted to the faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN SOIL SCIENCE**, embodies the result of a piece of *bona fide* research work carried out by **NABILA BINTA AFSAR, Registration no. 18-09303** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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Dedicated To
My Beloved
Parents

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The author

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LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
HRC	=	Horticulture Research Centre
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agriculture Organization
et al.	=	And others
TSP	=	Triple Superphosphate
MoP	=	Muriate of Potash
RCBD	=	Randomized Complete Block Design
DAT	=	Days after Transplanting
ha^{-1}	=	Per hectare
g	=	Gram (s)
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources Development Institute
wt	=	Weight
LSD	=	Least Significant difference
^0C	=	Degree Celsius
NS	=	Not Significate
Max	=	Maximum
Min	=	Minimum
%NPK	=	Nitrogen, Phosphorus and Potassium
CV%		Percentage of coefficient of variance

ABSTRACT

The experiment was carried out at the Farm of Sher-e-Bangla Agricultural University, Dhaka-1207 to find out the effect of nitrogen and boron on growth and yield of BARI Tomato-18 during the period of November 2019 to March 2020.The experiment comprised with four level of nitrogen viz. 0, 80, 120, 160 kg/ha., and three levels of boron viz. 0, 1.0, 1.5 kg/ha. The two factor experiment was set-up in Randomized Complete Block Design (RCBD) with three replications. In total, there were 12 treatment combinations in this study. A unit plot size was (1.8 m × 1.25 m i.e. 2.25 m^2) and the treatment were distributed randomly in each block. Data on growth and yield parameters were recorded and analyzed statistically. Results showed that individual and combined effects of nitrogen (N) and boron (B) were significant in variation of all growth and yield contributing characters. The highest plant height (137.67 cm), number of flower clusters per plant (14.33), flowers per cluster (15.33), fruits per cluster (13.0), fruits per plant (68.66), minimum required date for flowering (32.33 DAT), for fruiting (40.33 DAT) and for harvesting (88.33 DAT), fruit weight per plant (3.1700 kg), fruit weight per plot (18.45 kg), highest fruit yield (79.5 t/ha), highest fruit length (76.00 mm) and highest fruit diameter (44.333 mm) were recorded from the application of $N_{120}B_{1.0}$ treatment. On the other hand, the lowest yield of fruit (34.5 t/ha) and for all cases lowest result were found in control treatment. There were no significant effect on variation of N, P, K, S, pH, OC and OM concentration in post-harvest soil for the application of N and B. The maximum N content (0.086 %), P (21.33 ppm), K (0.17 meq/100 g soil) S (25.667 ppm), OC (0.72 %), OM (1.24 %) concentration were obtained at $N_{160}B_{1.5}$ treatment. It can be said that the interaction of 120 kg/ha N + 1.0 kg/ha B i.e. $N_{120}B_{1.0}$ treatment was best compared to others used in this experiment for growth and yield of BARI Tomato -18.

CHAPTER I

INTRODUCTION

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INTRODUCTION

Tomato (*Solanum lycopersicon* L.) is a common solanaceous vegetable, cultured throughout the world. It positions next to potato in respect of vegetable production in the world (FAO, 2010). And in Bangladesh, it grades 2nd which is next to potato (BBS, 2009) and chief list of canned vegetables. It is a self-fertilized yearly crop. It is cultivated all over country due to its flexibility to wide range of soil and climate (Ahmed, 1976). Its food valuation is very rich as a consequence of advanced contents of vitamin A, B, C as well as calcium, minerals, carotene and iron (Bose and Som, 1990). It is a nutritious and lovely vegetable used in salad, soups and processes into stable foodstuffs like ketchup, sauce, pickles, chutney and juice. Lycopene in tomato is a commanding antioxidant and lessens the risk of prostate cancer (Hossain, 2001).

Bangladesh hurts from unintentional and uninformed vegetables production all the year round. Maximum vegetables are formed in the winter. Tomato cultured in practically all home gardens and also in the fields for its flexibility to wide range of soil and climate in Bangladesh. The finest growing areas of tomato in Bangladesh are Chittagong, Comilla and Rajshahi (Hossain and Abdulla, 2015). It is produced all the year round but its peak season during December to March. In Bangladesh, the area under tomato production is 27,518.62 hectares through a total production of 3,89,000 metric tons taking an average yield of 14.05 t/ha (BBS, 2018) whereas, the world tomato production is 200.95 million tons from the area of 4.8 million hectares with an average yield of 41.45 t/ha (FAOSTAT, 2018). Unfortunately, the average yield of tomato in Bangladesh is very low compared to that of neighboring countries like China (56.2 t/ha) and India (24.2 t/ha) (Halder *et al*., 2003). This low yield of tomato in Bangladesh is not a symbol of low potentiality of the crop, but it may be due to numerous causes, for example, unavailability of good quality seeds of superior varieties and some improper management of cultural practices such as improper fertilizers, irrigation and disease control measures, etc. Fertilizer management practices are one of the most important cultural practices particularly in tomato due to the intensive cropping and gradual decline in soil nutrients. This situation can be improved by using proper fertilizer management (Tindall, 1983). It is necessary to discover the best productive variety with optimum fertilizer dose for maximum production (Latha *et al*., 2002).

Acceptable supply of nutrient can increase the yield, fruit quality, fruit size, keeping quality, color and test of tomato (Shukla and Naik, 1993). It needs large quantity of readily available fertilizer nutrient (Gupta and Shukla, 1977). Indeterminate type of tomato, vegetative and reproductive stage overlaps and the plants need nutrients up to fruit ripening. To grow one- ton fresh fruit, plants required to absorb on an average 2.5-3 kg N, 0.2-0.3 kg P and 3.0- 3.5 kg K (Hedge, 1997). In lack of other production constraints, nutrient uptake and yield are very closely related.

Nitrogen is the most warning nutrient to crop production (Pionke *et al*., 1990). It is critically deficient and is the most limiting component in soils of Bangladesh (Haque, 1983). Large amounts of nitrogen frequently lost to leaching below the root zone of vegetables crops (Pionke *et al*., 1990). Nitrogen fertilization, in consort with early season weed control, allows rapid crop establishment and growth, which is critical for the crop to suppress late emergence of weeds (Itulya *et al.,* 1997). Deficit of nitrogen results in poor growth and stunting of plants (Makasheva, 1983) and therefore reduction in crop yields (Machler *et al*., 1988; Radin *et al*., 1988). In general, starter dose of nitrogen fertilizer is being practiced in Bangladesh for the cultivation of tomato. Optimum plant density and nitrogen level in soil are the fundamentals for gaining higher yield of tomato. Nitrogen escalations the vegetative growth and delayed maturity of plants. Excessive use of this element may produce too much of vegetative growth, thus fruit production may be decreased (Singh *et al*., 1972). Nitrogen composition of plant tissue has significant nutritional consequences, since plants are a major source of proteins in human diet (Below, 1995). Nitrogen is also a component of a large number of important compounds found in living cells, for instance (enzymes) amino acids and nucleic acids (RNA and DNA) (Lea and Leegold, 1993). Hence, nitrogen is critical in improving growth, yield and quality of vegetables crops.

Micronutrients also play an important role in tomato production. Among the micro elements, boron shows an important role directly and indirectly in improving the yield and quality of tomato in addition to checking various diseases and physiological disorders (magalhaes *et al*., 1980). Boron affects the quality of tomato fruit, particularly size and shape, color, smoothness, firmness, keeping quality and chemical composition. Demoranville and Deubert (1987) reported that fruit shape, yield, and shelf life of tomato were also affected by boron. A positive connection was observed among boron and flower bud, number of flowers and weight of fruit in tomato (Bose *et al*., 2002)

Boron deficiency can cause sterility i.e. fewer fruits per plant attributing lower yield. Deficiency of B results restriction of water absorption and carbohydrate metabolism which last affect fruit and seed formation and therefore reduces yield. In fertilizer schedule, an addition of B often resolves the success and failure of the crops. It is described that the ranges between deficiency and toxicity of boron are quite narrow and that an application of boron can be extremely toxic to plants at concentrations only slightly above the optimum rate (Gupta *et al*., 2000). This highlights the need for judicial use of boron fertilizer.

Frequent research works have been carried out on fertilizer requirement and the effect of fertilizers on growth and yield of tomato in developed countries but information on systematic research on BARI Tomato -18 in Bangladesh is limited. Therefore, the present study was stated with the following objectives:

i. To observe the effect of N and B on the growth and yield of BARI Tomato - 18.
ii. To find out the optimum doses of N and B for maximizing the growth and yield of BARI Tomato - 18.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Nitrogen (N) and boron (B) are the most essential nutrient elements for exploiting the yield of tomato. The proper fertilizer management really influences its growth and yield performance. Frequent investigators in various parts of the world have investigated the response of tomato to different levels of N and B for its fruitful cultivation. In Bangladesh, available literature concerning fertilizer requirements for tomato is inadequate and often contradictory. However, some of the literature related to fertilizer requirements in tomato have been supplied in this chapter under the following headings:

2.1 Effect of nitrogen (N) on Tomato:

Shariful *et al.* (2019) conducted an experiment on tomato to evaluate the effect of nitrogen (N) and phosphorous (P) on the growth and yield component of tomato. They used four levels of N (N_0: 0 kg N/ha, N_{100}: 100 kg N/ha, N_{150}: 150 kg N/ha and N_{200}: 200 kg N/ha) and four levels of P (P_0: 0 kg/ha P_{50}: 50 kg /ha, P_{100}: 100 kg/ha and p_{150}: 150 kg/ha P_{2O5}: 205 kg/ha). They founded that number of flowers per plant, number of fruits of plant and fruit weight per plant increased significantly with increasing N level up to 200 kg N/ha, whereas fruit yield increased significantly up to 200 kg N/ha.

Beyene and Mulu (2019) conducted a field experiment in West showa zone, Toke kutaye district of Ormia region, Ethiopia with the objective to determine the optimum nitrogen fertilizer rate on different growth parameters, yield and yield component of tomato crop. They used four level of nitrogen fertilizer Viz., 0, 50, 100, and 150 kg/ha as treatments. Their experiment showed that, there was the significant ($P<0.05$) difference among treatments for all parameters except for number of fruit per cluster. For growth variables, 150 kg/ha revealed the highest value but there was no significant ($P<0.05$) difference between 100 and 150 kg/ha of nitrogen except for the height of the plant. The treatment 150 kg/ha nitrogen fertilizer provided 22.41, 35.57 and 25.40% over the control treatment in height, number of leaves and number of primary branch, respectively. The treatment 150 kg/ha nitrogen fertilizer increased the number of cluster per plant and yield of tomato fruit per hectare by 34.50 and 70.79% over the control treatment, respectively. However, they did not found any significant difference in both number of cluster per plant and yield per hectare between 150 and 100 kg N/ha.

Seran *et al.* (2016) conducted an experiment to evaluate the effect of NK chemical fertilizers in combination with compost on the growth and yield attributes of tomato. Their pot experiment was done in a complete randomized block design possessing eight treatments with four replicates. They found that there were significant differences in fruit and seed weights, total soluble solid, pulp weight, 100 seed weight, pulp consistency, leaf area and crop residue. In these parameters, higher mean values were recorded in chemical fertilizers (7.5 g N + 6 g K_2O + 15 g P_2O_5 per m^2) with compost (2 kg per m^2) than those in the chemical fertilizers applied alone (9.0 g N + 8 g K_2O + 15 g P_2O_5 per m^2 as standard control).

Biswas *et al*. (2015) conducted an experiment to study the growth and yield response of tomato. They used four nitrogen levels viz. Control: No nitrogen, N_1: 100 kg/ha, N_2: 150kg/ha and N_3: 200 kg/ha in a Randomized Complete Block Design with three replications. They found the tallest plant (91.4 cm) from N_2. They said that maximum number of leaves (97.8/plant), number of branches (10.7/plant), number of flowers (6.4/cluster), number of fruits (5.1/cluster), number of clusters (15.3/plant), fruit diameter (15.6 cm), individual fruit weight (73.1 g), yield (22.2 kg/plot and 61.4 t/ha) and total Soluble Solid (TSS) (5.5%) were found from N_2 while minimum from N_0. They found that 150 kg/ha nitrogen was best compared to other nitrogen level used in their experiment for growth and yield of BARI Tomato - 9.

Ferreira *et al*. (2010) studied that nitrogen fertilization efficiency of the tomato crop, with organic fertilization, was evaluated in two experiments conducted at two times: spring/summer and autumn/spring. In both times, the applied N doses, in the form of nitro calcium, were 0.0, 93.3, 187.0, 374.0 and 748.0 kg ha^{-1} and the doses of organic fertilization, in the form of cattle manure compost, were 0 and 8 t ha^{-1} of dry matter. They found the weight and the number of marketed tomatoes $plant^{-1}$ increased with the increase of N level in the soil. They said that in spring/summer, the productivity was higher without the addition of organic matter to the soil, whereas in the autumn/spring the reverse took place.

Kikuchi (2009) observed that growth and nitrogen content were different among nine tomato cultivars grown under three nitrogen levels (50, 100, 150 mg N/L). He said that applied nitrogen efficiency to growth was the highest in Odoriko', and the lowest in 'June Pink'. It was suggested that the difference in tomato growth was influenced not only by the difference of nitrogen uptake but also the difference of nitrogen efficiency ratio (dry weight per nitrogen content).

Tesfaye Balemi (2008) conducted a field experiment on vertisol at Ambo University College (Ethiopia) during 2003-2004 and 2004-2005 cropping seasons to study the response of tomato cultivars varying in growth habit to rates of Nitrogen (N) and Phosphorus (P) fertilizers and plant spacing. He used a factorial combination of two cultivars (Margelobe and Melka shola), three NP fertilizers rates (50 kg N + 60 kg P_2O_5/ha, 80 kg N + 90 kg P_2O_5/ha and 110 kg N + 120 kg P_2O_5/ha) and three spacing (100 cm x 30 cm, 80 cm x 30 cm and 60 cm x 45 cm) arranged in a Randomized Complete Block Design. He found that fertilizer rates and spacing significantly affected the total and marketable fruit yields as well as % marketable fruit yield. Similarly, plant vigor (plant height), number of fruits per cluster and 10 fruit weight were significantly influenced by all of the main factors. He suggested that the application of 110 kg N + 120 kg P_2O_5/ha or 80 kg N + 90 kg P_2O_5/ha resulted in significantly higher total as well as marketable fruit yield of the tomato cultivars.

Rahman *et al.* (2007) conducted a field experiment in order to calculate the growth, N uptake and yield of tomato by using four N levels (0, 100, 200 and 300 kg·ha-^{1}). They founded that, by applying 300 kg·ha-^{1} of N, plants had higher dry mass yield (about 13.0 t·ha-^{1}). Fresh matter, total, and marketable fruit yield improved from 0 to 100 and 200 kg·ha-^{1} of N (6.6, 5.5, and 4.2 kg/plant, respectively), while with increasing levels the same variables showed a decreasing trend. They said that greater number of total and marketable fruits per plant (160 and 109, respectively) can be yielded by supplying 200 kg·ha-^{1} of N. They found that crop N uptake linearly increased from the control (176 kg·ha-^{1}) to the highest N dose (339 kg·ha-^{1}).

An investigation was carried out by Bhadoria *et al.* (2007) to evaluate the effect of methods of Azotobacter inoculation in combination with nitrogen rates on the flowering and fruiting behavior of tomato cv. JT-99. They used three methods of inoculation (no inoculation, soil inoculation and seedling inoculation) and five nitrogen rates (0, 25, 50, 75 and 100 kg/ha). They found that seedling treatment with Azotobacter recorded the earliest flowering, fruit setting and picking of fruits, as well as higher number of flowers, fruits and yield/ha.

Solaiman and Rabbani (2006) carried out a field experiment was at the Bangabandhu Sheikh Mujibur Rahman Agricultural University farm in Bangladesh, to calculate the effects of inorganic and organic fertilizers on vegetative, flowering and fruiting characteristics as well as yield attributes and yield of Ratan variety of tomato. The plots were treated with three levels each of N (62, 100 and 200 kg ha^{-1}), P (11.7, 17.5 and 35 kg ha^{-1}), K (26.7, 40 and 80 kg ha^{-1}), S (5, 7.5 and 15 kg ha^{-1}) and cowdung (5, 10 and 15 t ha^{-1}). They got the highest plant height and dry weight of shoot, the maximum number of clusters of flowers and fruits $plant^{-1}$ as well as the greatest fruit size and fruit yield $plant^{-1}$, fruit yield ha^{-1} from the application of the recommended dose of nutrients viz. 200 kg N + 35 kg P + 80 kg K + 15 kg S ha^{-1}, but similar results were obtained from the treatment receiving 5 t cow dung ha^{-1} along with half of the recommended doses of nutrients (100 kg N + 17.5 kg P + 40 kg K + 7.5 kg S ha^{-1}).

Parisi *et al.* (2006) studied to influence of nitrogen supply (from 0 to 250 kg N ha^{-1}) on yield and quality constituents of processing tomato grown in 2002-03 in Sele valley (Campania, Italy). They suggested that nitrogen fertilizer application from 50 to 250 kg ha^{-1} increased total yield but not marketable yield, because of a strong increase of unmarketable yield and the higher rates of N from 150 kg ha^{-1} did not increase higher yield. They said that the highest rate supply resulted in less focused ripeness, more phytosanitary problems and an increase of viral damage incidence on fruits.

Singh *et al.* (2005) conducted an experiment to study the effects of N, P, and K at 200:100:150, 350:200:250, and 500:300:350 kg ha^{-1} on the growth and yield of tomato hybrids Rakshita, Karnataka, and Naveen in New Delhi, India during the early winter of 2000-02. Naveen had the highest number of flower clusters per plant and the earliest picking period and fruit setting. On the other hand, Karnataka produced the highest yield during both years (2.85 and 3.07 kg $plant^{-1}$). They got the highest plant height, number of leaves $plant^{-1}$, leaf length, stem thickness, number of flower clusters $plant^{-1}$, and picking period with the application of 500:300:350 kg NPK ha^{-1} during both years. Fruit yield (30.2 and 34.8 kg ha^{-1} in 2000-01 and 2001-02, respectively) and number of pickings (14 during both years) were the highest with the application of 350:200:250 kg NPK ha^{-1}.

Badruddin and Dutta (2004) reported that N requirement based on nitrate reductase (NR) induction, N accumulation and productivity. They used N fertilizer at 0, 75, 100, 125, 150 and 175 kg ha^{-1}, in 2 split-doses (24 and 40 days after transplanting). Fruit yield increased compared to the control. Nitrogen @ 175 kg ha^{-1} produced the highest straw yield. Straw N content was the highest (3.11%) with 100 kg N ha^{-1} in Mymensingh, while the highest N content (3.07%) in Rangpur was obtained with 125 kg N ha^{-1}. The highest fruit N accumulation (156 kg ha^{-1}) in Mymensingh was obtained with 175 kg N ha^{-1}, while 150 kg N ha^{-1} produced the highest fruit N accumulation (170 kg ha^{-1}) in Rangpur. There was a significant NR activity throughout the growing period of Bahar, which maintained the highest NR activity.

Warner *et al.* (2004) used five N fertilization rates in each of 4 years (0, 50, 100, 150 and 200 kg N ha^{-1} in 1999 and 0, 100, 150, 200 and 250 kg N ha^{-1} in 2000, 2001 and 2002). Total fruit yield increased linearly as N rate was increased except in 2001, which was a dry year. Responses of marketable yield to fertilizer N rate were dependent on cultivar and the year. In years when sufficient soil water was available, N fertilizer rates of 200 kg ha^{-1} or higher were required to produce the maximum marketable yield for the four cultivars. They said that in the dryer years, the response to fertilizer N rate was cultivar dependent, and the application of 150 to 200 kg N ha^{-1} was sufficient to maximize marketable yield.

It was hypothesized by Li *et al*. (2003) that soil N variability, and fertilization and cropping management affect potato (Solanum tuberosum L.) growth and fertilizer N efficiency. The N treatments which they used, consisted of a control, side-dress at rates of 70, 105 and 140 kg ha^{-1}, and split applications (at seeding and bloom) at rates of 70+70, 105+70 and 140+70 kg ha^{-1}, respectively. Soil acidity was corrected with limestone following the plow down of the sod. Years of cropping, main effect of N treatment, and year and fertilizer N interaction were significant on total and marketable tuber yields and N uptake, which were significantly related to soil N, and root growth.

A field experiment was conducted at Bhubaneswar, India by Sahoo *et al*. (2002) to study the effects of nitrogen (50, 100, 150 or 200 kg N ha^{-1}) and potassium (75 or 150 kg ha^{-1}) on the growth and yield of tomato var. Utkal kumara during the rabi season of 1999-2000. They said that the combination of 150 kg N/ha along with 75 kg K ha^{-1} gave best result with respect to tomato from yield and other yield attributing characters.

Ceylan *et al.* (2001) conducted an experiment at Odemis, Izmir, Turkey to observe the effect of ammonium nitrate and urea fertilizers at 0, 12, 24, 36 kg N ha^{-1} on nitrogen uptake and accumulation in tomato plants. In their experiment, total nitrogen, NO_2-N and NO_3-N contents of 16 leaves and fruits were determined. On the first and second harvest dates, the highest NO_3-N and NO_2-N amounts in tomato leaves and fruits were obtained upon treatment with 36 kg N ha^{-1}. The highest yield was recorded upon treatments with 24 kg N ha^{-1}.

A field study was undertaken by Khalil *et al*. (2001) in Peshawar, Pakistan in the summer of 1995-96 to determine the appropriate nitrogen fertilizer for maximum tomato (cv. Peshawar Local) yield and its effects on various agronomic characters of tomato. Treatments comprised: untreated control; 150 kg ammonium nitrate/ha; 150 kg ammonium nitrate/ha + 100 kg P/ha + 50 kg K/ha; 150 kg ammonium sulfate; 150 kg ammonium sulfate/ha + 100 kg P/ha + 50 kg K/ha; 150 kg urea/ha; 150 kg urea/ha + 100 kg P/ha + 50 kg K/ha. Generally, ammonium sulfate fertilizer was the most efficient source of nitrogen for tomato production, followed by urea and ammonium nitrate. They found that the ammonium sulfate + P + K treatment was the best among all treatments with respect to days to flower initiation (57 days), days to first picking (94 days), weight of individual fruit (50.8 g), weight of total fruits per plant (1990 g) and yield (21865 kg/ha).

Ravinder *et al*. (2000) found in experiments at Solan in 1996 and 1997, where eight tomato hybrids (Meenakashi, Manisha, Menka, Solan Sagun, FT-5XEC-174023, EC174023XEC-174041, Rachna and Naveen) were treated with four NPK combinations (100:75:55; 150:112.5:82.5; 200:150:110; 250:187.5:137.5 kg N:P_2O_5:K_2O ha^{-1}). The number of marketable fruits per plant and yield per plant were highest in Menka followed by Manisha. Of the fertilizers treatments, 200:150:110 kg N:P_2O_5:K_2O ha^{-1} produced the highest yields.

Gupta and Sengar (2000) found that tomato cv. Pusa Gaurav was treated with N at 0, 40, 80 and 120 kg/ha and K at 0, 30 and 60 kg/ha in a field experiment conducted in Madhya Pradesh, India during rabi 1992-93 and 1993-94. N application resulted in rises in plant height, number of fruits per plant, fruit weight and fresh yield.

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

Rhoads *et al.* (1999) carried out an experiment to evaluate the influence of N rates and ground cover following tomato on soil Nitrate-N movement was monitored in spring and autumn crops grown at the Florida A&M University, Florida, USA. Nitrogen rates varied from 0 to 360 lb. /acre in the spring crop and from 0 to 600 lb. /acre in autumn tomato. Yield ranged from 1900 to 2600 boxes/acre in spring tomato, and from 1300 to 2700 boxes/acre in autumn tomato. Fertilizer N rates above 180 lb. /acre were excessive, as shown by yield and residual soil nitrate N levels.

2.2 Effect of boron (B) on Tomato:

Ahmet Turhan (2020) conducted an experiment on interactive effects of boron stress and mycorrhizal (AMF) treatments on tomato growth, yield, leaf chlorophyll and boron accumulation, and fruit characteristics. They found that high levels of boron (B) in soils cause toxicity in tomatoes, but inoculation of *arbuscular mycorrhizal* fungi (AMF) into plants can reduce it. They evaluated the effects of AMF inoculation on morphological parameters (shoot height, plant fresh and dry weights), yield, leaf chlorophyll and boron content, and fruit characteristics (weight, water and soluble solid contents, firmness, color) of tomato plants grown in boron stress (0.06, 0.5, 1.0, 2.0, 4.0, and 8.0 mM). They said that increased boron concentrations reduced all parameters except leaf boron content, fruit soluble solids and firmness. However, the highest values of the morphological parameters, fruit soluble solid contents and red color values (control, 0.5 and 1.0 mM B), fruit yield (<8.0mM B), leaf chlorophyll content (≤2.0mM B), fruit weight (control, 0.5 and 2.0 mM B), fruit firmness (control and 1.0 mM B) were obtained from mycorrhizal plants.

Sanjida *et al.* (2020) conducted an experiment to investigate the effects of varieties and boron (B) levels on growth and yield of summer tomato (*Lycopersicon esculentum* Mill.) at the Germplasm Centre in the Department of Horticulture, Patuakhali Science and Technology University, Patuakhali during the period from May, 2018 to September, 2018. They used fifteen treatments that were comprising (i) three summer tomato varieties (BARI hybrid tomato 4, 8 and 10) and (ii) five levels of boron as boric acid (0, 1, 2, 3 and 5 kg B ha^{-1}) in all combinations. They said that the boron levels at final count $plant^{-1}$, early flowering (29.67 days), the maximum no. of flower clusters (18.44), no. of flowers (89.11), no. of fruits (46.22) and total weight of fruits (2364.29 g) were recorded in 2 kg B ha^{-1} treatment; the maximum plant height (96.50 cm), no. of leaves (102.89), no. of branches (28.11), longest fruit length (42.89 mm) and maximum fruit width (46.78 mm) and weight of individual fruit (51.74 g) were obtained in 3 kg B ha^{-1} treatment.

Osman *et al*. (2019) conducted an experiment to investigate the effect of boron and zinc on the growth and yield of tomato. Three levels of boron (viz., 0, 1 and 2kg H_3B0_3 ha^{-1}) and zinc (viz., 0, 1 and 2kg $ZnS0_4$ ha^{-1}) were applied for each experiment. Results revealed that boron had significant effect on all yield attributes and yield of tomato. Application of 2 kg H_3B0_3/ha produced the highest tomato yield (79.2-ton ha^{-1}) through increasing plant height, number of leaves per plant, number of branches per plant, number of flower clusters per plant, number fruits per plant, weight of fruits per plant, fruit weight, individual fruit length, fruit diameter and yield ha^{-1} of fruits. On the other hand, maximum yield of tomato was obtained from 2 kg $ZnS0_4$ ha^{-1}. A combination of 2 kg H_3B0_3 and 2 kg $ZnS0_4$ ha^{-1} gave the highest yield of Tomato (83.50-ton ha^{-1}). They suggested that the application of 2 kg H_3B0_3 along with 2 kg $ZnS0_4$ ha^{-1} was the best for growth and yield of tomato.

Harris and Puvanitha (2015) done an experiment at the Crop farm, Eastern University, Sri Lanka during the period of December 2013 to April 2014 to find out the response of foliar application of H_3BO_3 and $CuSO_4$ on growth and yield of tomato. Treatments were arranged in Completely Randomized Design (CRD) and replicated eight (8) times. There were 10 treatments namely, (T1) H_3BO_3 =150 ppm; (T2) H_3BO_3 = 250 ppm; (T3) H_3BO_3= 350 ppm; (T4) $CuSO_4$= 150 ppm; (T5) $CuSO_4$= 250 ppm; (T6) $CuSO_4$= 350 ppm; (T7) H_3BO_3 (150 ppm) + $CuSO_4$ (150 ppm); (T8) H_3BO_3 (250 ppm) + $CuSO_4$ (250 ppm); (T9) H_3BO_3 (350 ppm) + $CuSO_4$ (350 ppm); (T10) Control.

Shaimaa *et al.* (2014) carried out an experiment on effect of boron on growth and some physiological activities of tomato plant. They said that tomato is one of the crops which respond well to boron application. In their experiment a germination and pot experiments were conducted in order to assess the possible effects of boron (0.0, 100, 200, 300 and 400 ppm) on the growth and some metabolic activities of tomato at 9 and 30 days of growth. They found that application of different concentrations of boron significantly increased fresh and dry weights at low boron concentrations (100 and 200 ppm) compared with control. In addition, the content of Ca and B were increased in shoot and root of tomato, K was increased in shoot and decreased in root, while Na increased in root and decreased in shoot in response to boron application.

Naz *et al.* (2012) conducted an experiment to study the effect of Boron (B) on the growth and yield of Rio Grand and Rio Figue cultivar of tomato at Horticultural Research farm, NWFP Agricultural University, Peshawar during 2008-2009. They used different doses of B (0, 0.5, 1.0, 2.0, 3.0 and 5.0 kg/ha) with constant doses of nitrogen, phosphorus and potash was incorporated at the rate of 150, 100, 60 kg/ha. The experiment was laid out in randomized Complete Block Design with 2 factors. They founded that 2 kg B/ha resulted in maximum number of flower clusters per plant, fruit set percentage, total yield, fruit weight loss and total soluble solid.

Salam *et al.* (2011) carried out at the Vegetable Research Farm of the Horticulture Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur to investigate the effect of boron, zinc, and cow dung on quality of tomato. There were 16 treatments comprising four rates of boron and zinc viz., BoZno. $B_{1.5}Zn_2$ B_2Zn_4 and $B_{2.5}$ Zn_6 kg/ha and four rates of cow dung viz., CDo, CD_{10}, CD_{15}, and CD_{20} t/ha. Every plot received 253 kg N, 90 kg P, 125 kg K, and 6.6 kg S per hectare. The results reflected that the highest pulp weight (90.24%), dry matter content (5.82%), ascorbic acid (11.2 mg/100g). lycopene content (147 μg/100g), chlorophyll-a (42.0 μg/l00g), chlorophyll-b (61.0 μg/100g), boron content (36 μg/g), zinc content (51 μg /g), marketable fruits at 30 days after storage (74%) and shelf life (17 days) were recorded with the combination of 2.5 kg B/ha + 6 kg Zn/ha, and 20 t/ha cow dung.

Salam *et al*. (2010) conducted an experiment at the vegetable research farm of the Horticulture Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during the period 2006-2007 to investigate the effects of boron and zinc in presence of different levels of NPK fertilizers on quality of tomato. There were twelve treatment combinations which comprised four levels of boron and zinc viz., i) B_0Zn_0=

0 kg B + 0 kg Zn/ha, ii) $B_{1.5}Zn_{2.0}$= 1.5 kg B + 2.0 kg Zn/ha, iii) $B_{2.0}Zn_{4.0}$ = 2.0 kg B + 4.0 kg Zn/ha, iv) $B_{2.5}Zn_{6.0}$= 2.5 kg B + 6.0 kg Zn/ha and three levels of NPK fertilizers viz., i) 50% less than the recommended NPK fertilizer dose (50% RD). The highest pulp weight (88.14%), dry matter content (5.34%), TSS (4.50%), acidity (0.47%), ascorbic acid (10.95 mg/100g), lycopene content (112.00 µg/100g), chlorophyll-a (41.00µg/100g), chlorophyll-b (56.00 µg/100g), marketable fruits at 30 days after storage (67.48%) and shelf life (16 days) were recorded with the combination of 2.5 kg B+ 6 kg Zn/ha and recommended dose of NPK fertilizers (N= 253, P= 90, and K= 125 kg/ha).

Rahman *et al.* (2007) conducted a field experiment at the research farm of Sher-e-Bangla Agricultural University, Dhaka, during November 2006 to March 2007 to study the effects of nitrogen and boron on growth and yield of tomato. They used four levels of each of Nitrogen (N_0=0, N_1=60, N_2=120 and N_3=180 kg N ha^{-1}) and 3 levels of Boron (B_0=0, B_1= 0.4 and B_2= 0.6 kg B ha^{-1}) in all possible combinations were applied following a randomized block design with three replications. They found that with increasing the levels of N, all the yield contributing characters and yield of tomato increased up to the 120 kg N ha^{-1}. Application of N @ 120 kg ha^{-1} gave the highest plant height (122.46 cm), flower clusters $plant^{-1}$ (9.67), flowers $cluster^{-1}$ (10.44), fruits $cluster^{-1}$ (6.76), fruits $plant^{-1}$ (52.44), fruit weight $plant^{-1}$ (1.60 kg), fruit weight $plot^{-1}$ (19.14 kg) and fruit yield (48.33 t ha^{-1}). On the contrary, application of B @ 0.6 kg ha^{-1} gave the highest values of all these parameters. In interaction, N @ 120 kg ha^{-1} along with B @ 0.6 kg ha^{-1} produced the highest plant height (142.2 cm), flower clusters $plant^{-1}$ (12.67), flowers $cluster^{-1}$ (11.67), fruits $cluster^{-1}$ (6.33), fruits $plant^{-1}$ (67.33), fruit weight $plant^{-1}$ (1.953 kg), fruit weight $plot^{-1}$ (23.20 kg) and fruit yield (58.59 t ha^{-1}). The highest N and B content in plants were observed from 180 kg N ha^{-1}.

Smit and Combrink (2004) observed that insufficient fruit set of tomatoes owing to poor pollination in low cost greenhouses is a problem in South Africa. Four nutrient solutions with only B at different levels (0.02; 0.16; 0.32 and 0.64 mg L^{-1}) were used. Leaf analyses indicated that the uptake of Ca, Mg, Na, Zn and B increased with higher B levels. At the low B level, leaves were brittle and appeared pale-green and very high flower abscission percentages were found. The highest B-level had no detrimental effect on any of the yield and quality related parameters.

Ben and Shani (2003) stated that Boron is essential to growth at low concentrations and limits growth and yield when in excess. The influences of B and water supply on tomatoes (*Lycopersicon esculentum* Mill.) were investigated in lysimeters. Boron levels in irrigation water were 0.02, 0.37, and 0.74 mol m^{-3}. Conditions of excess boron and of water deficits were found to decrease yield and transpiration of tomatoes. Both irrigation water quantity and boron concentration influenced water use of the plants in the same manner as they influenced yield.

Chude *et al*. (2001) reported that plant response to soil and applied boron varies widely among species and among genotypes within a species. This assertion was verified by comparing the differential responses of Roma VF and Dandino tomato cultivars to a range of boron levels in field trials at Kadawa (11° 39' N, 8° 2' E) and Samaru (11° 12', 7° 37' E) in Sudan and northern Guinea savanna, respectively, in Nigeria. Boron levels were 0, 0.5, 1.0, 1.50, 2.0 and 2.5 kg/ha replicated three times in a randomized complete block design. Treatment effects were evaluated on fruit yield and nutritional qualities of the two tomato cultivars at harvest. Total soluble solids, titratable acidity and reducing sugar contents of the two cultivars differed significantly (P=0.05). Generally, Dandino contained higher amounts of these indexes than Roma VF. This cultivar seems to be more B efficient than Roma VF even at low external B level**.**

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

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, under the agro ecological zone of Modhupur Tract (AEZ-28) throughout Rabi season of 2019 (October 2019 to March 2020) to evaluate the effect of nitrogen (N) and boron (B) on the growth and yield of BARI Tomato-18. This chapter presents the picture of soil, crop, experimental design, treatments, cultural operations, collection of soil and plant samples and also the analytical methods which are followed in the experiment.

3.1 Experimental site and soil

The experiment was conducted in a typical rice growing soil of the farm of Sher-e-Bangla Agricultural University, Dhaka during Rabi season of 2019. This site was located at 23.75 N latitude and 90.34 E longitudes with an elevation of 4 meter from the sea level (Anonymous. 1988). (Fig. 1). The soil of the experimental site goes to the general soil type, Deep Red Brown Terrace Soil under Tejgaon Series. The land was above the flood level and during the experimental period there was available sufficient sunshine. The soil samples were lifted from the experimental plots to a depth of 0-15 cm from the surface before starting of the experiment and analyzed in the laboratory. The morphological, physical and chemical characteristics of initial soil are presented in Table 1 and 2.

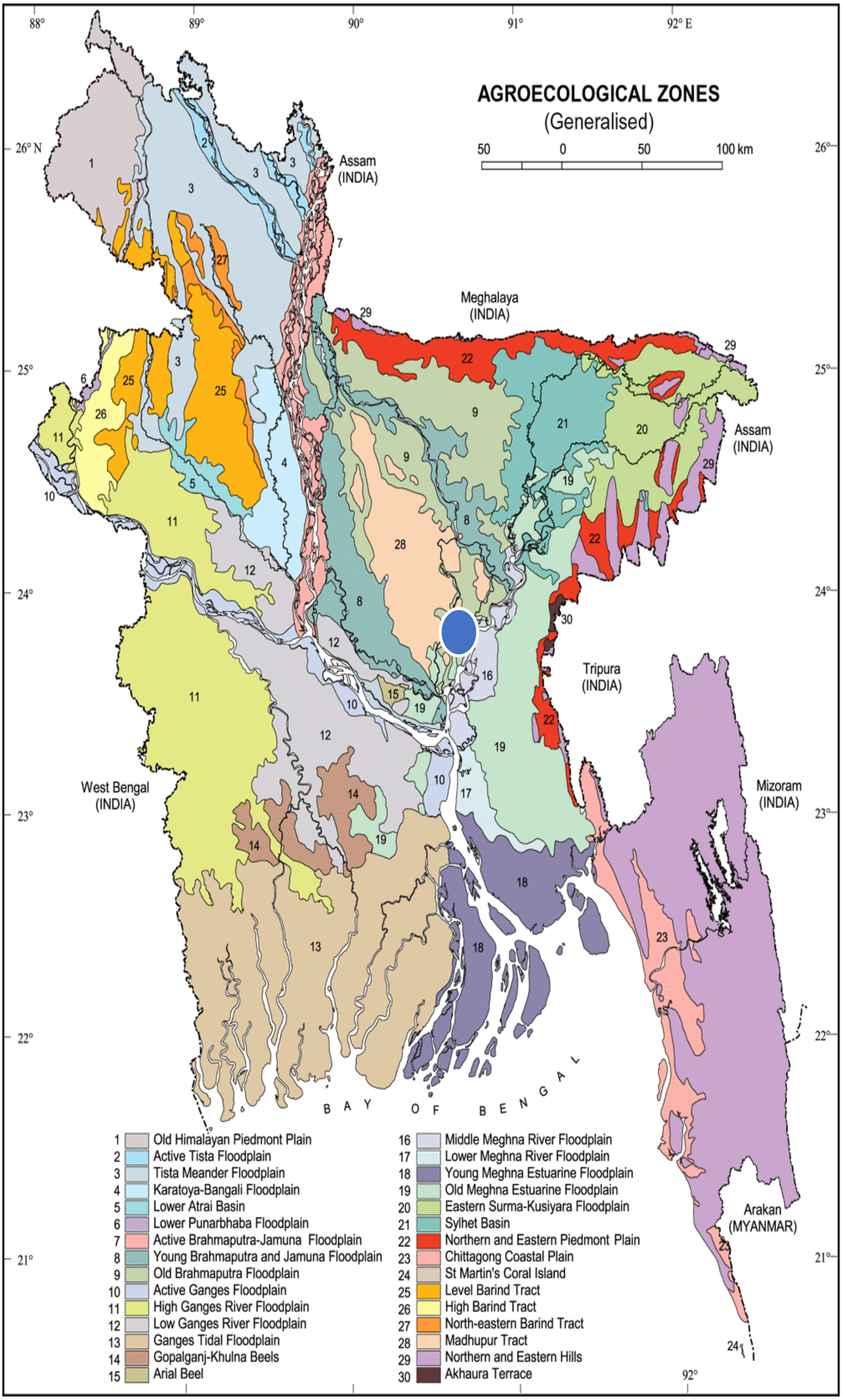

Figure.1. Map showing the experimental site under study

Table 1. Morphological Characteristics of experimental field

Morphological Features	Characteristics
Location	Sher-e Bangla Agricultural University Farm, Dhaka
AEZ No. and name	AEZ-28, Modhupur Tract
General soil type	Deep Red Brown Terrace Soil
Soil Series	Tejgaon
Topography	Fairly leveled
Depth of Inundation	Above flood level
Drainage condition	Well drained
Land type	High land

Table 2. Physical and chemical properties of the experimental soil

Soil properties	Value
A. Physical properties	
1. Particle size analysis of soil.	
% Sand	30
% Silt	40
% Clay	30
2. Soil texture	Clay loam
B. Chemical properties	
1. Soil pH	6.01
2.Particle density	2.45
3. Organic carbon (%)	0.65
4. Organic matter (%)	1.12
5. Total N (%)	0.06
7. Available P (ppm)	20
8. Exchangeable K (meq/100g soil)	0.12
9. Available S (ppm)	23

3.2 Climate

Sub-tropical climate has been characterized of the experimental area by heavy rainfall during May to September and scant rainfall during rest of the year. Information regarding average monthly rainfall, temperature is recorded by Bangladesh Meteorological Department (Climate division) during the period of study. The average temperature and rainfall data during the cropping period are shown in Appendix I.

3.3 Seeds and variety

BARI Tomato-18, a high yielding variety of tomato (*Lycopersicon esculentum*) developed by Bangladesh Agricultural Research Institute (BARI), Gazipur at 2017 was used as test crop. Average marketable fruits per plant is 37, average fruit weight 95 g, yield per plant 3.3 kg, and yield/ha is 75 tons. It is determinate type plant. It is free from virus diseases. Seeds were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur.

3.4 Raising of seedlings

Tomato seedlings were raised in a seedbed of 3 m x 1 m size. The soil was well prepared and converted into loose friable and dried mass by spading. All the stables and the stubbles were removed and 10 kg well rotten cow dung was mixed with the soil. Five gram of seeds were sowed on the seedbed, according to the date. The seeds were sowed in the seedbed on 31 October, 2019. Sevin 85 SP was applied around the seedbed as precautionary measure against ants, worm and other harmful insects. The emergence of the seedlings took place with 5 days after seed sowing. Shading by polythene with bamboo structure was provided over the seedbed to protect the young seedlings from scorching sunshine or rain. Diathane M 45 was sprayed in the seedbed @ 2 g L^{-1}, to protect the seedlings from damping off and other diseases. Weeding, mulching and irrigation were done as and when required.

3.5 Design and layout of experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications of each fertilizer treatment combinations. Fertilizer treatments consisted of 4 levels of N (0, 80, 120 and 160 kg N ha^{-1} designated as N_0, N_{80}, N_{120} and N_{160}, respectively) and 3 levels of B (0, 1.0 and 1.5 kg B ha^{-1} designated as B_0, B_1 and $B_{1.5}$ respectively). There were 12 treatment combinations. The treatment combinations were as follows:

N_0B_0 = Control (without N and B application)

$N_0B_{1.0}$ = 0 kg N/ha+1.0 kg B/ha

$N_0B_{1.5}$ = 0 kg N/ha+1.5 kg B/ha

$N_{80}B_0$= 80 kg N/ha+0 kg B/ha

$N_{80}B_{1.0}$= 80 kg N/ha+1.0 kg B/ha

$N_{80}B_{1.5}$= 80 kg N/ha+1.5 kg B/ha

$N_{120}B_0$ =120 kg N/ha+0 kg B/ha

$N_{120}B_{1.0}$ = 120 kg N/ha+1.0 kg B/ha

$N_{120}B_{1.5}$ = 120 kg N/ha+1.5 kg B/ha

$N_{160}B_0$ = 160 kg N/ha+0 kg B/ha

$N_{160}B_{1.0}$ = 160 kg N/ha+1.0 kg B/ha

$N_{160}B_{1.5}$ = 160 kg N/ha+1.5 kg B/h

The experiment was laid out in Randomized Complete Block Design (RCBD) having 12 treatments and three replications. An area was divided into three equal blocks. Each block was consisting of 12 plots where 12 treatments were allotted randomly. So for there were 36 unit plots altogether in the experiment. The size of each plot was 1.8 m × 1.25 m i.e. 2.25 sq. m. The row-to-row and plant to plant distance were 60 cm and 40 cm, respectively accommodating 8 plants in each plot. The adjacent block and neighboring plots were separated by 0.5 m and 0.25 m, respectively. The layout of the experiment is shown in Figure 2.

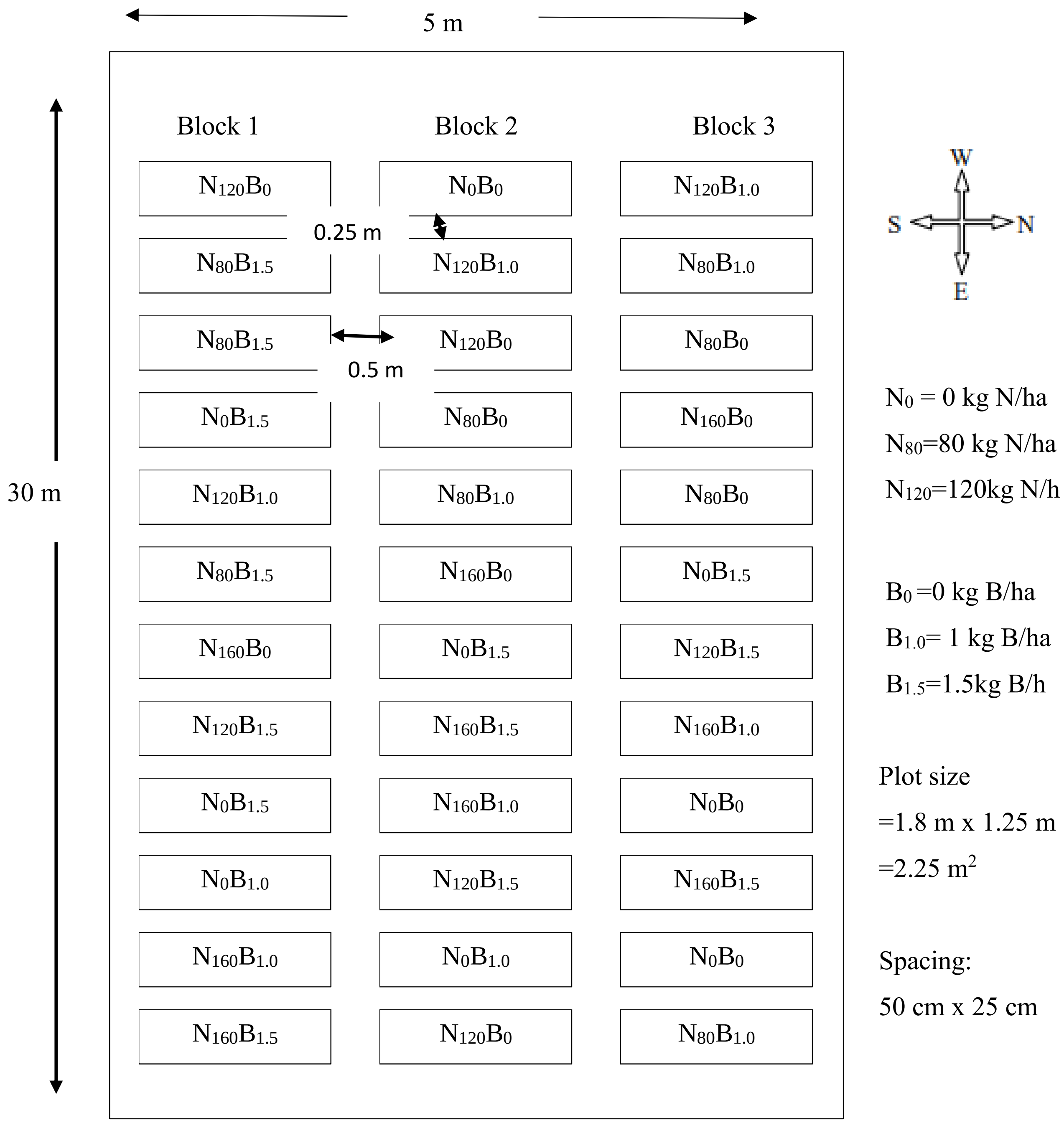

Figure 2. Layout of the experiment in the Randomized Complete Block Design (RCBD)

3.6 Collection and processing of soil sample

The initial soil samples were collected before land preparation from 15 cm soil depth. The samples were drawn by an augur from different location of the plot and mixed thoroughly to make composite sample. After collection of soil samples, plant roots, leaves etc. were picked up and removed. After that the samples were air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis.

3.7 Land preparation

The land was first ploughed with a tractor drawn disc plough on 22 November. 2019. Ploughed soil was brought into desirable tilth condition by four operations of ploughing and harrowing with country plough and ladder. The stubbles of the previous crops and weeds were removed. The land operation was completed on 24 November. 2019.

3.8 Application of fertilizers

The P, K, S and Zn fertilizer were applied according to Fertilizer Recommendation Guide (BARC, 2015) through Triple Super Phosphate (TSP), Muriate of Potash (MoP), Gypsum and Zinc Oxide, respectively. One third (1/3) of whole amount of Urea and MoP, and full amount of TSP, Gypsum, Zinc Oxide and Boric acid were applied at the time of final land preparation. The remaining Urea and MoP were applied in two equal installments- at 15 days after transplanting (DAT) and 35 DAT respectively.

Table 3. Doses of fertilizer and its method of application

Fertilizers	Dose/ha	Application (%)		
		Basal	15 DAT	35 DAT
N	As per treatment	----	50	50
P	36 kg	100	----	----
K	80 kg	----	50	50
S	15 kg	100	----	----
Zn	2.0 kg	100	----	----
B	As per treatment	100	----	----

3.9 Transplanting of seedlings

Healthy and uniform sized seedlings which were 25 days old, were taken from the seed bed and were transplanted in the experimental field on 25 November, 2019 maintaining a spacing of 60 cm and 40 cm between the rows and plants, separately. The seed bed was watered before uprooting the seedlings so as to minimize the damage of the roots. This operation was carried out during late hours in the evening. The seedlings were watered after transplanting.

3.10 Intercultural Operation

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

3.10.1 Gap filling

When the seedlings were developed the soil around the base of each seedling was pulverized. A few gaps filling was done by healthy plants from the border whenever it was required.

3.10.2 Weeding and Mulching

Weeding and mulching were accomplished as and whenever necessary to keep the crop free from weeds, for better soil aeration and to break the soil crust. It also helped in the soil moisture conservation. Different types of weeds were controlled manually for the first time and removed from the field on 17 December 2019. Second and third weeding were done on 31 December, 2019 and 15 January, 2020, respectively.

3.10.3 Stacking and Pruning

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

3.10.4 Irrigation and Drainage

Light irrigation was provided immediately after transplanting of the seedlings and it was continued till the seedlings established through the irrigation channel. Thereafter irrigation was done as per when needed. There also drained out the stagnant water effectively at the time of heavy rain.

3.10.5 Earthing up

Earthing up was done at 20 and 40 days after transplanting on the basement of plant by taking the soil from boundary side of plots by hand.

3.11 Pest management

Science the experimental field was located beside the radish field, and the BARI tomato-18 variety is virus diseases infestation free, and it has 7% bacterial infestation, I didn't use any pesticide or insecticide.

3.12 Harvesting

At 5 days' intervals during maturity to ripening stage the fruits had been harvested. The crop maturity was determined on the basis of fruits' red coloring. Harvesting was started from 26 February, 2020 and completed by 20 March, 2020.

3.13 Parameters assessed

Five plants from each plot were selected as random and were tagged for the data collection. The sample plants were uprooted and dried properly in the sun. Data were collected on the following parameters:

1. Plant height at harvesting (cm)
2. Number of flower cluster per plant
3. Number of flowers per cluster
4. Number of fruits per cluster
5. Number of fruits per plant
6. Days to 1^{st} flowering
7. Days to 1^{st} fruiting
8. Days to 1^{st} harvesting
9. Weight of fruits per plant (kg)
10. Fruit diameter in length and width (mm)
11. Yield (kg/plot)
12. Yield (t/ha)

3.14 Data Collection

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

3.14.1 Plant Height (cm)

The plant height was recorded from the sample plants after harvesting through a cm scale.

3.14.2 Number of Flower Cluster/Plant

The number of flower clusters was counted from the sample plants and the average number of the clusters borne per plant was recorded till the flowering happened. The data of cluster/plant is presented only the average of flower cluster at 45 and 65 DAT.

3.14.3 Number of flowers per cluster

The number of flowers per cluster was counted from the sample plants and the average number of the flowers per cluster was recorded till the flowering happened. The data of flowers/cluster is presented only the average of flower at 45 and 65 DAT.

3.14.4 Number of fruits per cluster

Total number of fruits was counted from selected cluster and their average was taken as the number of fruits per cluster at harvest.

3.14.5 Number of fruits per plants

Total number of fruits was counted from selected plants and their average was taken as the number of fruits per plant at harvest.

3.14.6 Days to 1st flowering (DAT)

Days required for transplanting to initiation of flowering was recoded from the date of transplanting to the initiation of flowering.

3.14.7 Days to 1st fruiting (DAT)

Days required for transplanting to initiation of fruiting was recoded from the date of transplanting to the initiation of fruiting.

3.14.8 Days to 1st harvesting (DAT)

Days required for transplanting to harvesting was recoded from the date of transplanting harvesting.

3.14.9 Length and Width of Fruit (mm)

The length and width of fruit was measured with slide calipers from the neck of the bottom and one side to another side respectively from five selected marketable fruits and their average was taken in mm as the length of fruit.

3.14.10 Yield (kg/ plant)

From five sample plants the fruits were harvested and they were measured by a measuring balance and the average was taken by following formula:

$$\text{Yield per plant (kg)} = \text{Total weight of fruits in 5 sample plants} \div 5$$

3.14.11 Yield (ton/ ha)

The yield per hectare was calculated from per plot yield data. As per plot size was 2.25 m^2, so the average yield was taken by following formula:

$$\text{Yield per hectare (ton)} = ((\text{Yield per plot} \times 10000) \div 2.25) \div 1000$$

3.15 Methods for Soil Analysis

Soil samples were analyzed for both physical and chemical characteristics viz. particle density, soil pH, total N, available P, K, S, organic matter, and organic carbon contents. The soil samples were analyzed by the following standard methods as follows:

3.15.1 Particle size analysis of soil

For the initial soil, particle size analysis was done by hydrometer method (Bouyoucos, 1927). The textural class was determined using Marshall's Triangular Co-ordinate as designated by USDA.

3.15.2 Total Nitrogen (%)

Total nitrogen of the soil was determined by Micro kjeldahl method where soil was digesting by 30 % H_2O_2, conc. H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se powder in the ratio of 100:10:1). The digested nitrogen was estimated by distillation with 40% NaOH followed by titration of the distillate trapped in H_3BO_3 with 0.01N H_2SO_4.

The amount of N was calculated by using the following formula:

$$\% N = \frac{(T - B) \times N \times 0.014 \times D}{W} \times 100$$

Where,

T Sample titration (ml) value of standard H_2SO_4

B= Blank titration (ml) value of standard H_2SO_4

N= Strength of H_2SO_4

W= Oven dry weight of supplied soil sample

D= Dilution factor

3.15.3 Available Sulphur (ppm)

Available Sulphur in soil was determined by extracting the soil samples with 0.15% $CaCl_2$ solution (page *et al.,* 1982). The S content in the extract was determined turbidimetrically and the intensity of turbid was measured by spectrophotometer at 420 nm wave length.

3.15.4 Available phosphorus (ppm)

Available phosphorus was extracted from soil by shaking with 0.5 M $NaHCO_3$ solution of pH 8.5 (Olsen *et al* 1954). The P in the extract was then determined by developing blue color using $SnCl_2$ reduction of phosphomolybdate complex. The absorbance of molybdophosphate blue color was measured at 660 nm wave length by spectrophotometer and available P was calculated with the help of standard P curve (Page *et al*.1982).

3.15.5 Available potassium (meq/100 g soil)

Exchangeable K was determined by 1N NH_4OAc (pH 7) extraction methods and by using flame photometer and calibrated with a standard curve (Page *et al*. 1982).

3.15.6 Organic carbon (%)

Organic carbon of the soil was determined by Wallkley and Black's (1934) wet oxidation method. The underlying principle is to oxidize the organic carbon with an excess of 1 N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and to titrate the residual $K_2Cr_2O_7$ solution with 1 N $FeSO_4$ solution. The result was expressed in percentage.

3.15.7 Soil Organic Matter (%)

Soil organic matter content was calculated by multiplying the percentage value of organic carbon with the Van Bemmelen factor, 1.724.

$$\% \text{ organic matter} = \% \text{ organic carbon} \times 1.724$$

3.15.8 Soil pH

The pH of the soil was determined with the help of a glass electrode pH meter using soil: water ratio being 1:2.5 (Jackson, 1973).

3.16 Statistical Analysis

The data in respect of growth and yield components and soil chemical parameters were statistically analyzed by using STATISTIX 10 package programmed to find out the significance of the experimental results. The means of all the treatments were calculated and the analysis of variance for each of the characters under study was performed by F test. The difference among the treatment means was evaluated by Least Significant Difference (LSD) test (Gomez and Gomez, 1984) at 0.05% level of probability.

CHAPTER IV

RESULT AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

This Chapter includes the experimental result along with discussion. The results of the experiment conducted under field conditions are presented in several tables and figures. The experiment was conducted to study the effect of different levels of Nitrogen and Boron on the performance of BARI Tomato- 18 in RCBD. Individual and combined effects of N and B on different yield and yield contributing characters of tomato and different chemical component in post-harvest soil are shown in the tables of (4- 15). The analysis of the variance (ANOVA) of the data on different components are given in Appendix (II- IV). The results have been presented and discussed, and possible explanations have been given under the following headings:

4.1 Yield and yield contributing characters of tomato

Yield contributing characters such as plant height, days to transplanting to first flowering, first fruiting and first harvesting, number of flower cluster per plant, number of flower per cluster, number of fruits per cluster, number of fruits per plant, weight of fruits per plant, yield per plot and hectare, diameter of fruits were recorded.

4.1.1 Plant height

Plant height varied significantly due to the application of different levels of nitrogen and boron. Plant height of tomato was significantly increased by different levels of nitrogen (Fig. 3). The tallest plant (127.89 cm) was produced at N_{160} which is 160 kg N/ha. The shortest plant (63.44 cm) was found in control treatment. It was observed that plant height increased gradually with the increment of nitrogen dose. This might be happened due to higher availability of nitrogen that enhanced the vegetative growth of the plant. These are compliance with those of Ali *et al.* (1990), Mondal and Gaffar (1983), Gaffer and Razzaque (1983), who have reported that increasing levels of nitrogen significantly increased plant height.

There was positive and significant difference among the different levels of boron in respect of plant height (Fig. 4). Plant height increased with increased level of boron up to higher level. The tallest plant (105.58 cm) was produced at $B_{1.0}$ treatment which is 1.0 kg/ha B and it was statistically similar with treatment of $B_{1.5}$ (102.67 cm). The shortest plant (91.25 cm) was found at control treatment. This indicated that higher level of boron increased plant height.

The treatment combinations of nitrogen and boron had high significant effect on plant height (Table 6). The tallest plant (137.67 cm) was found in $N_{120}B_{1.0}$ treatment. The shortest plant (53.33 cm) was found in the control treatment. These results expressed that medium dose of boron and higher dose of nitrogen were influential nutrients for increasing the plant height.

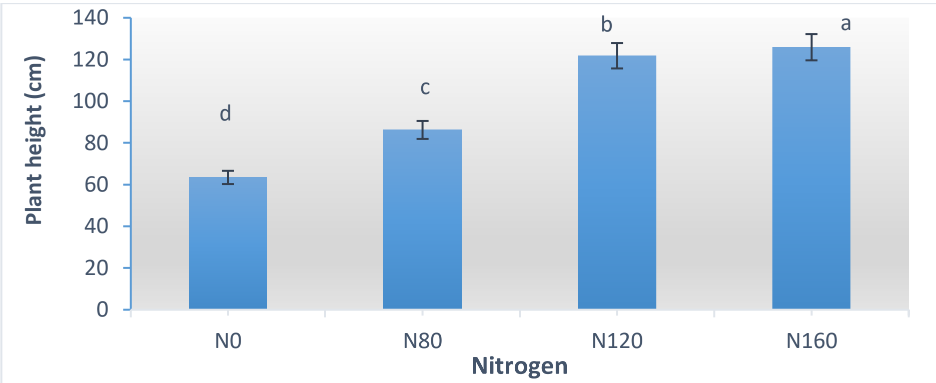

Figure 3. Effect of different level of nitrogen on plant height

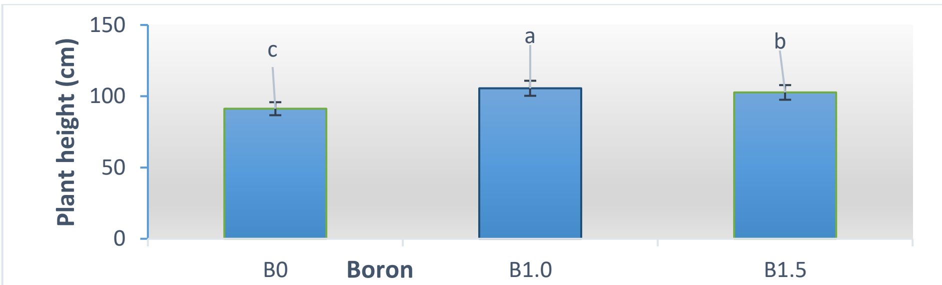

Figure 4. Effect of different level of boron on plant height

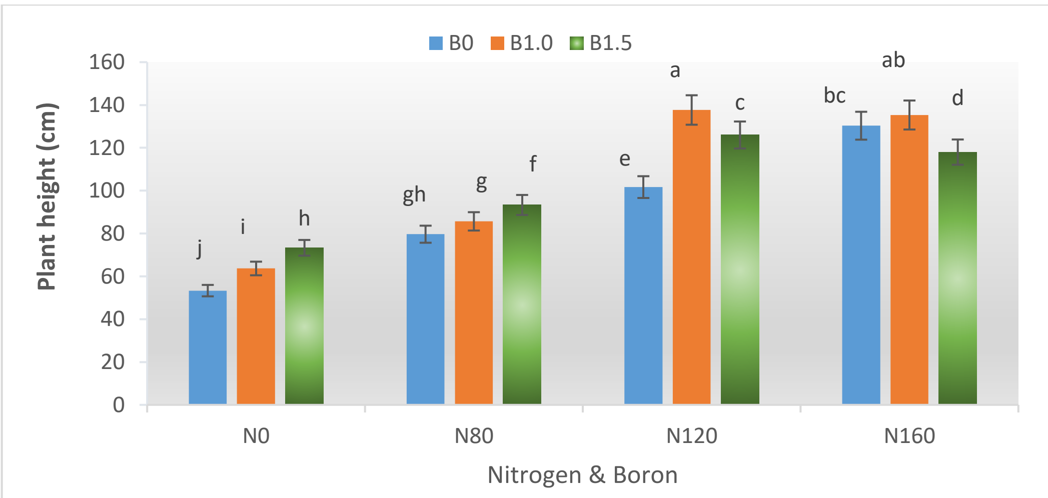

Figure 5. Effect of different level of nitrogen-boron combination on plant height

4.1.2 Number of flower cluster per plant

Number of flower cluster per plant progressively increased with increasing level of N (Table 4) and it was highly significant. The highest number of flower per cluster (13.00) was produced at N_{60} treatment and lowest number of flower cluster per plant (5.88) was found at control treatment. It is evident from the results that the application of increasing number of N increased the number of flower cluster per plant. Grela *et al.* (1988) reported that the number of flowers was increased with the increasing level of nitrogen.

By the application of B, the number of flower cluster increased positively (Table 5) and it was highly significant. The maximum number of flower cluster per plant (10.25) was found at $B_{1.5}$ treatment. The minimum number of flower cluster per plant (8.41) was recorded at B_0 treatment.

Interaction effect of N and B on the number of flower cluster per plant was highly significant (Fig. 6). The highest number of flower cluster per plant (14.33) was found in $N_{120}B_{1.0}$ and lowest (5.33) was found at control which was statistically similar with $N_0B_{1.0}$. The second highest number of flower per cluster (13.00) was found at treatment of $N_{120}B_{1.5}$.

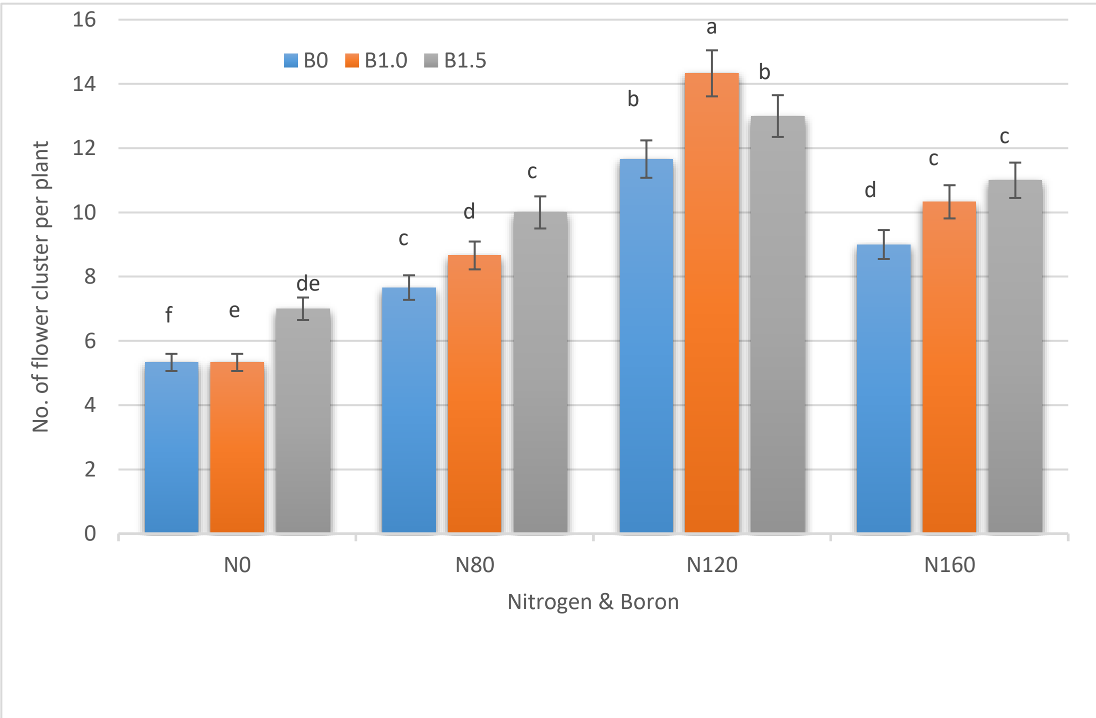

Figure 6. Effect of nitrogen-boron combination on number of flower cluster per plant

Table 4. Effect of nitrogen on the growth parameters of tomato

Treatment	Plant height at harvest (cm)	No. of flower cluster/ Plant	No. of flower/ cluster	No. of fruit/ cluster	No. of fruit/ Plant
N_0	63.44 d	5.88 d	6.55 d	3.556 d	29.44 d
N_{80}	86.22 c	8.77 c	9.88 c	6.55 c	45.44 c
N_{120}	121.8 b	10.11 b	14.11 a	11.33 a	62.66 a
N_{160}	127.89 a	13.00 a	10.55 b	8.33 b	55.11 b
LSD $_{(O.05)}$	3.91	0.53	0.63	0.08	0.58
CV (%)	4.01	5.80	6.32	7.55	3.18

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

N_0: 0 kg N/ha i.e. control N_{80}: 80 kg N/ha N_{120}: 120 kg N/ha N_{160}: 160 kg N/ha

Table 5. Effect of boron on the growth parameter of tomato

Treatment	Plant height at harvest (cm)	No. of flower cluster/ plant	No. of flower/ cluster	No. of fruit/ cluster	No. of fruit/ Plant
B_0	91.25 c	8.41 c	9.75 c	6.75 c	44.66 c
$B_{1.0}$	105.58 a	9.66 b	10.33 b	8.16 a	50.58 a
$B_{1.5}$	102.67 b	10.25 a	10.75 a	7.41 b	49.25 b
LSD $_{(O.05)}$	3.38	0.46	0.54	0.07	0.50
CV (%)	4.01	5.80	6.32	7.55	3.18

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

B_0: 0 kg B/ha i.e. control $B_{1.0}$:1.0 kg B/ha $B_{1.5}$: 1.5 kg B/ha

Table 6. Combined effect of nitrogen - boron on the growth parameters of tomato

Treatment	Plant Height at Harvest (cm)	No. of Flower Cluster /Plant	No. of Flower/ Cluster	No. of Fruit/ Cluster	No. of Fruit/ Plant
N_0B_0	53.33 j	5.33 h	5.33 f	3.33 g	24.44 j
$N_0B_{1.0}$	63.67 i	5.33 h	6.66 e	3.66 g	29.00 i
$N_0B_{1.5}$	73.33 h	7.00 g	7.66 de	3.66 g	35.3 h
$N_{80}B_0$	79.67 gh	7.66 g	10.00c	6.00 f	41.33 g
$N_{80}B_{1.0}$	85.67 g	8. 66 f	8.667 d	7.00 e	44.66 f
$N_{80}B_{1.5}$	93.33 f	10.00 e	11.00 c	6.66 ef	50.33 e
$N_{120}B_0$	101.67 e	11.66 c	13.66 b	9.66 c	56.00 d
$N_{120}B_{1.0}$	137.67 a	14.33 a	15.33 a	13.00 a	68.66 a
$N_{120}B_{1.5}$	126.00 c	13.00 b	13.33 b	11.33 b	63.33 b
$N_{160}B_0$	130.33 bc	9.00 f	10.00 d	8.00 d	57.33 d
$N_{160}B_{1.0}$	135.33 ab	10.33 de	10.66 c	9.00 c	60.00 c
$N_{160}B_{1.5}$	118.00 d	11.00 cd	11.00 c	8.00 d	48.00 e
LSD $_{(O.05)}$	6. 77	0.92	1.09	0.95	2.59
CV (%)	4.01	5.80	6.32	7.55	3.18

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

4.1.3 Number of flowers per cluster

Number of flower per cluster progressively increased with increasing level of N (Table 4) and highly significant. The highest number of flower per cluster (14.11) was produced by N_{120} treatment. Lowest number of flower per cluster (6.55) was found at control treatment. It is evident from the results that the application of increasing number of N increased number of flower per cluster. Grela *et al*. (1988) reported that the number of flowers was increased with the increasing level of N up to a certain level.

By the application of B, the number of flower per cluster increased positively (Table 5) which was statistically significant. The maximum number of flower per cluster (10.75) was found with the application of $B_{1.5}$ treatment which was statistically similar with $B_{1.0}$ (10.33). The minimum number of flower per cluster (9.75) was recorded at control treatment.

Interaction effect of N and B on the number of flower per cluster was significant (Table 6). The highest number of flower per cluster (15.33) was found in $N_{120}B_{1.0}$ treatment and lowest (5.33) was found at control treatment.

4.1.4 Number of fruits per cluster

There was highly significant difference on number of fruits per cluster due to application of different level of N (Table 4). Number of fruits per cluster increased with increasing level of nitrogen up to a certain level, then it decreased with increasing level of nitrogen. The maximum amount of fruit per cluster (11.33) was found at N_{120} treatment. The minimum number of fruit per cluster (3.556) was found at control treatment.

The statistical variation of number of fruit per cluster was significant with increasing level of B application up to a certain level (Table 5). The highest number of fruits per cluster (8.16) was found in $B_{1.0}$ treatment and lowest number (6.75) was found in control treatment.

The effect of treatment combinations of nitrogen and boron on number of fruits per cluster was significant and the number increased with increasing level of combination up to a certain level (Table 6). The highest fruit per cluster (13.00) was obtained in $N_{120}B_{1.0}$ treatment combination. The lowest number of fruit per cluster (3.33) was found at control treatment which was statistically similar with $N_0B_{1.0}$ and $N_0B_{1.5}$.

4.1.5 Number of fruits per plant

The effect of different levels of N on the number of fruits per plant was highly significant (Fig. 7). Number of fruits per plant increased gradually with increasing level of nitrogen up to certain level, then it decreased with increasing level of nitrogen. The maximum number of fruits per plant (62.66) was obtained at N_{120} treatment. The minimum number of fruit per plant (29.44) was obtained at control treatment. It revealed that the increasing level of N increased the number of fruits per plant.

The variation of the number of fruits per plant was statistically significant by application of different level of boron (Fig. 8). The highest number of fruit per plant (50.58) was obtained at $B_{1.0}$ treatment. The lowest number of fruits per plant (44.66) found at control treatment.

The interaction effects of nitrogen and boron on the number of fruits per plant were significant (Fig. 9). The highest number of fruits per plant (68.66) was found at $N_{120}B_{1.0}$ treatment. The lowest number of fruit per plant (24.00) was found at control treatment.

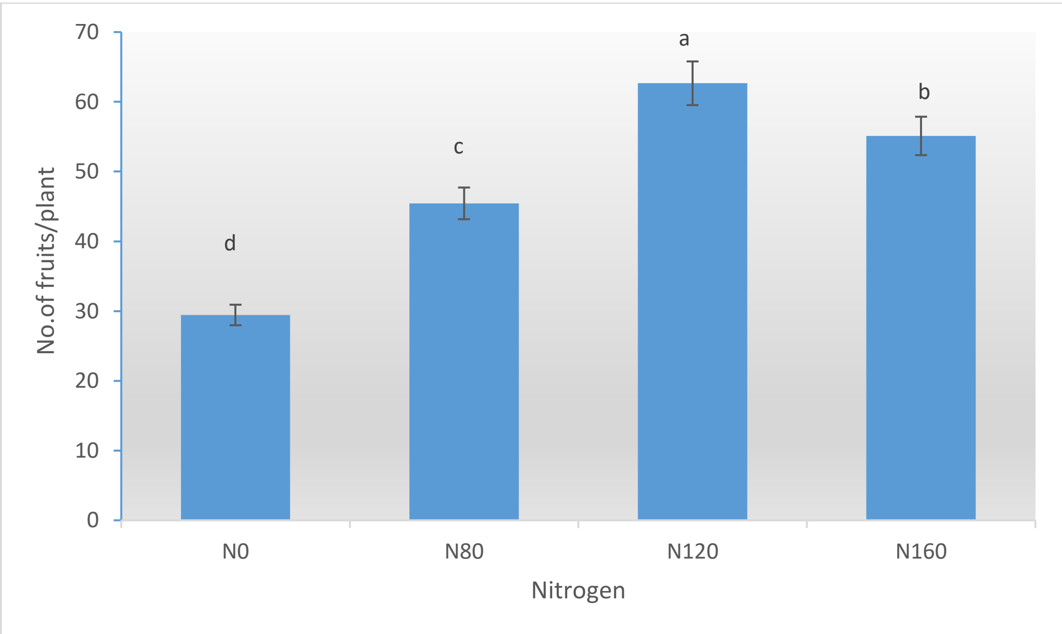

Figure 7. Effect of different level of nitrogen on number of fruits per plant

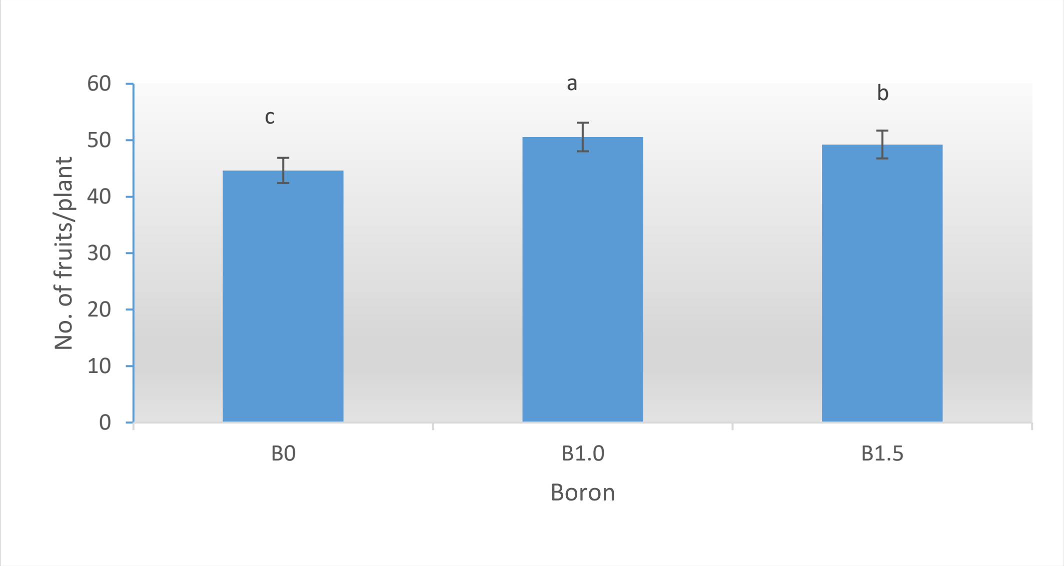

Figure 8. Effect of different level of boron on number of fruits per plant

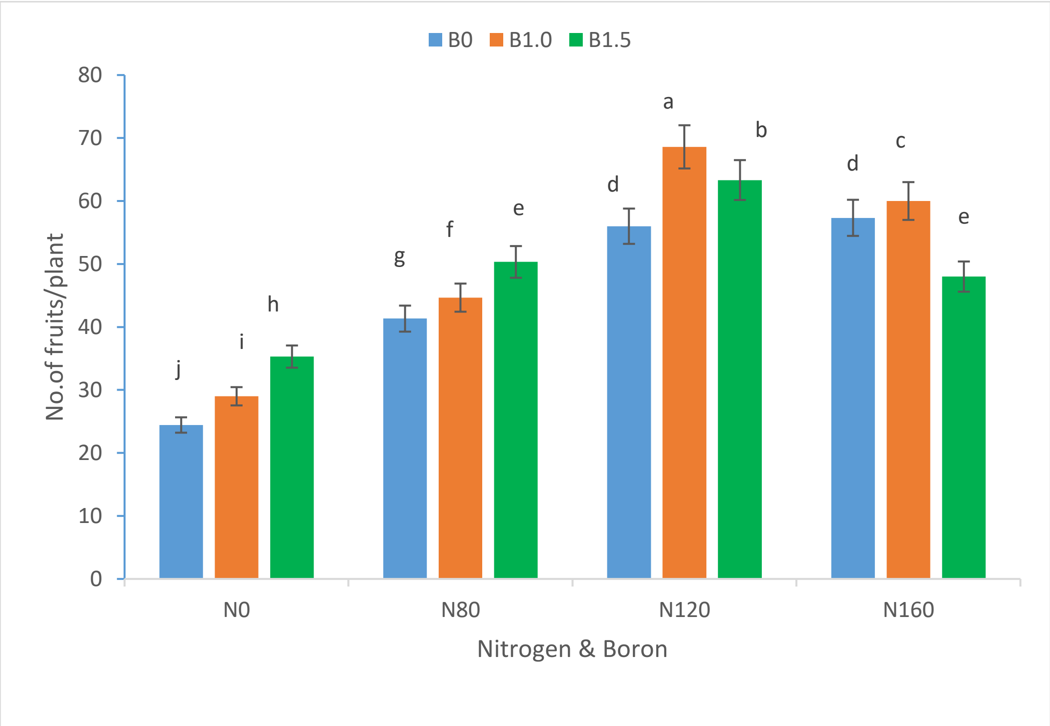

Figure 9. Effect of different level of nitrogen-boron combination on number of fruits per plant

Table 7. Effect of nitrogen on days to flowering, fruiting and harvesting

Treatment	Days to 1st flowering	Days to 1st fruiting	Days to 1st harvesting
N_0	40.11 a	51.66 a	106.0 a
N_{80}	37.11 b	48.55 b	99.89 b
N_{120}	33.667 c	42.77 d	91.67 d
N_{160}	34.55 c	44.88 c	94.89 c
LSD (O.05)	1.09	1.50	3.07
CV (%)	3.09	3.27	3.20

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

N_0: 0 kg N/ha i.e. control N_{80}: 80 kg N/ha N_{120}: 120 kg N/ha N_{160}: 160 kg N/ha

Table 8. Effect of boron on days to flowering, fruiting and harvesting

Treatment	Days to 1st flowering	Days to 1st fruiting	Days to 1st harvesting
B_0	36.08 b	47.33 a	99.58 a
$B_{1.0}$	37.08 a	47.66 a	97.41 b
$B_{1.5}$	35.91 b	45.91 b	97.33 b
LSD (O.05)	0.95	1.30	2.65
CV (%)	3.09	3.27	3.20

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

B_0: 0 kg B/ha i.e. control $B_{1.0}$:1.0 kg B/ha $B_{1.5}$: 1.5 kg B/ha

Table 9. Effect of nitrogen and boron combination on days to flowering, fruiting and harvesting

Treatment	Days to 1st flowering	Days to 1st fruiting	Days to 1st harvesting
N_0B_0	39.33 ab	52.66 a	107.0 a
$N_0B_{1.0}$	40.33 a	51.00 ab	103.3 ab
$N_0B_{1.5}$	40.66 a	51.33 ab	107.6 a
$N_{80}B_0$	35.66 c	48.00 cde	104.00 ab
$N_{80}B_{1.0}$	37.66 b	50.33 abc	100.67 bc
$N_{80}B_{1.5}$	38.00 b	47.33 de	95.00 d
$N_{120}B_0$	35.67 c	46.00 e	93.67 d
$N_{120}B_{1.0}$	32.33 d	40.33 g	88.33 e
$N_{120}B_{1.5}$	33.00 d	42.00 fg	93.00 de
$N_{160}B_0$	33.66 d	42.66 fg	93.67 d
$N_{160}B_{1.0}$	38.00 b	49.00 bcd	97.33 cd
$N_{160}B_{1.5}$	32.00 d	43.00 f	93.67 d
LSD $_{(O.05)}$	1.90	2.60	5.31
CV (%)	3.09	3.27	3.20

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

4.1.6 Days from transplanting to first flowering

The effect of different levels of N on first flowering date was highly significant (Table 7). The minimum required days after transplanting to first flowering (34.556 DAT) was recorded from treatment of N_{160} which was statistically similar with N_{120} (33.667 DAT) and maximum required days from transplanting to first flowering (40.111 DAT) was recorded at treatment of control.

The effect of different level of boron on first flowering date was significant (Table 8). The minimum required days after transplanting to first flowering (35.917 DAT) was recorded at $B_{1.5}$ treatment and the maximum required days after transplanting to first flowering (37.083 DAT) was recorded at $B_{1.0}$ treatment.

The interaction effect of nitrogen and boron on first flowering date was significant (Table 9). The minimum required days from transplanting to first flowering (32.00 DAT) was recorded from treatment of $N_{160}B_{1.5}$ and maximum required days from transplanting to first flowering (40.667 DAT) was recorded at treatment of $N_0B_{1.5}$ which was statistically similar with N_0B_0 and $N_0B_{1.0}$.

4.1.7 Days from transplanting to fruiting

Different levels of nitrogen significantly affected the parameter of first fruiting (Table 7). The minimum required date from transplanting to fruiting (42.778 DAT) was recorded from the treatment of N_{120}. The maximum required date from transplanting to fruiting (51.667 DAT) was recorded at control treatment. It indicated that higher amount of nitrogen up to certain level provided early fruiting.

The effect of different levels of boron on days from transplanting to fruiting were significant (Table 8). The minimum required date from transplanting (45.917 DAT) to fruiting was found at $B_{1.5}$ treatment and the maximum required date (47.667 DAT) was recorded at $B_{1.0}$.

The effects of combination of nitrogen and boron on days from transplanting to fruiting were significant (Table 9). The minimum required date from transplanting to fruiting (40.33 DAT) was recorded from $N_{120}B_{1.0}$ treatment. The maximum required date from transplanting to fruiting (52.66 DAT) was recorded at the control treatment.

4.1.8 Days from transplanting to harvesting

Different level of nitrogen significantly affected the first harvesting date (Table 7). The minimum required date from transplanting to harvesting (91.67 DAT) was observed at N_{120} and maximum required date from transplanting to harvesting (106.0 DAT) was observed at control.

The effect of different level of boron had no significant effect on first harvesting date (Table 8). The minimum required date from transplanting to harvesting (97.33 DAT) was found at $B_{1.5}$ treatment which was statistically similar with $B_{1.0}$ (97.44 DAT) and $B_{1.5}$ (99.58 DAT) that was maximum.

The interaction effect of nitrogen and boron on days from transplanting to harvesting were significant (Table 9). The minimum required date from transplanting to harvesting (88.33 DAT) was found at $N_{120}B_{1.0}$ treatment. The maximum required date from transplanting to harvesting (107.0 DAT) was at control treatment which was statistically similar with $N_0B_{1.5}$.

4.1.9 Fruit weight (kg/plant)

By different level of nitrogen, fruit weight of tomato significantly affected (Table 10). Fruit weight per plant increased with increasing level of N. The maximum weight of fruit per plant (2.9311 kg) was obtained at N_{160} treatment. The minimum weight of fruit per plant (1.3433 kg) was obtained at control treatment.

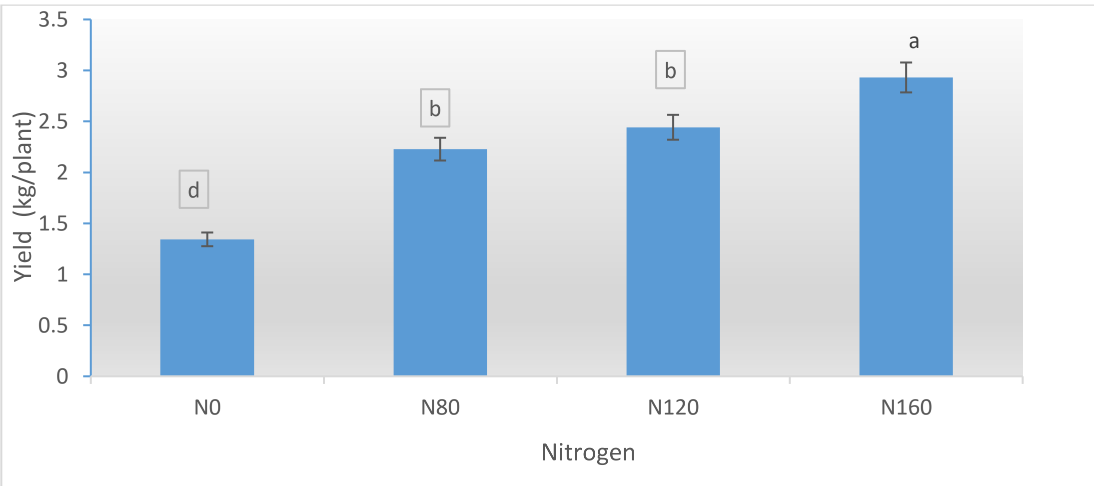

Figure 10. Effect of different level of nitrogen on yield (kg/plant)

Fruit weight per plant were significantly affected by different levels of boron (Table 11). The highest weight of fruit per plant (2.3517 kg) was found at $B_{1.5}$ treatment which was statistically similar with $B_{1.0}$ (2.2625 kg) treatment. The lowest weight of fruit per plant (2.0942 kg) was obtained at control treatment. It was observed that fruit weight per plant was increased with increasing level of boron.

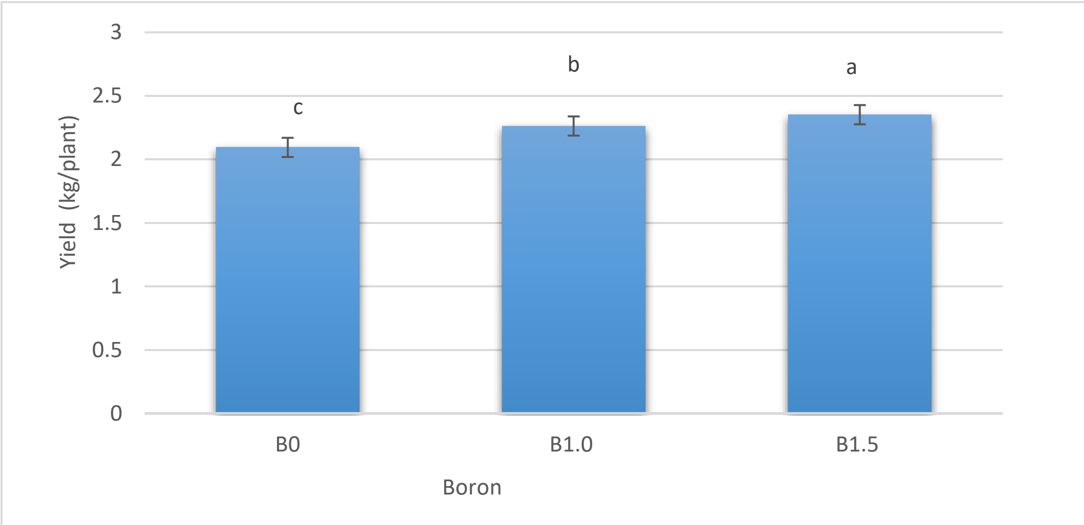

Figure 11. Effect of different level of boron on yield (kg/plant)

Different treatment combinations of N and B significantly affected the fruit weight of tomato per plant (Table 11). The highest weight of fruit per plant (3.1700 kg) was found in $N_{120}B_{1.0}$ treatment and the lowest weight of fruit per plant (1.2167 kg) was found at control treatment which was statistically similar with the treatment of $N_0B_{1.0}$.

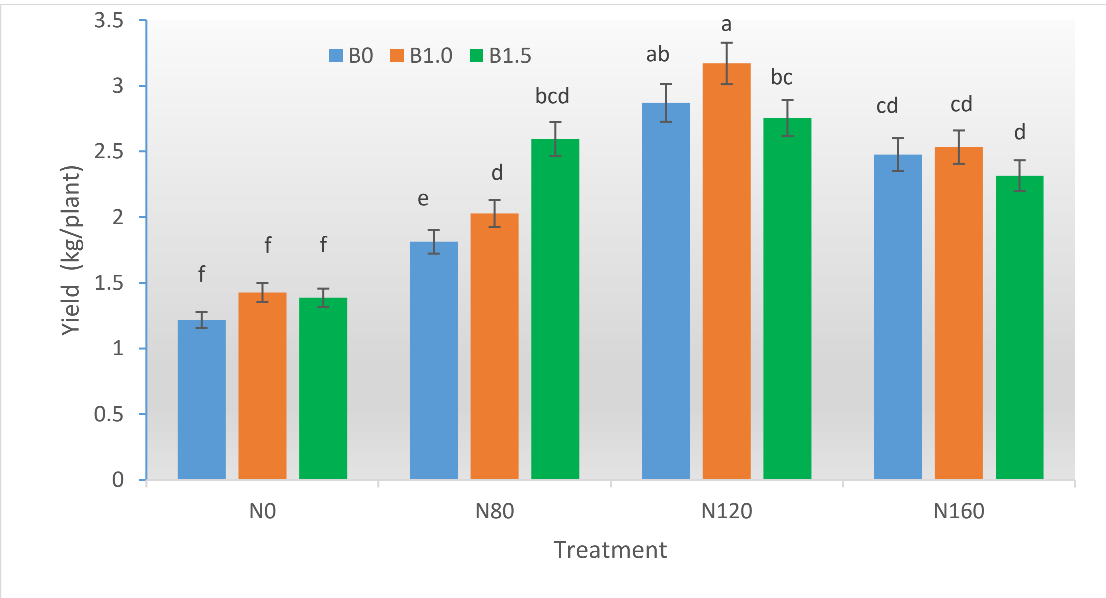

Figure 12. Interaction effect of nitrogen and boron on yield (kg/plant)

4.1.10 Fruit weight (kg/plot)

Fruit weight per plot of tomato was significantly affected by different level of nitrogen (Table 10). By receiving N at the rate of 160 kg/ha i.e. N_{160} treatment produced significantly higher weight of fruit per plot (15.51 kg) which was statistically similar with the treatment of N_{120} (15.33 kg). The lowest weight of fruit per plot (8.41 kg) was obtained at control treatment.

Fruit weight per plot was significantly affected by different level of boron (Table 11). The absence of boron (B_0) provided the lowest weight of fruit per plot (11.24 kg). The highest weight of fruit per plot (13.12 kg) was recorded at $B_{1.0}$ treatment.

The interaction effect of nitrogen and boron on fruit weight per plot was significant (Table 12). The treatment combination of $N_{120}B_{1.0}$ provided the highest weight of fruit per plot (18.45 kg) and the second highest weight of fruit per plot (17.37 kg) was found at $N_{160}B_0$ treatment. The control treatment gave the lowest fruit weight per plot (7.71 kg).

4.1.11 Fruit yield (ton/ha)

The increasing level of N up to 160 kg per hectare significantly increased the fruit yield of tomato (Fig. 13). Application of 120 kg N/ha i.e. N_{120} treatment provided the maximum yield of tomato (68.93.ton/ha). The minimum yield of tomato (37.39 ton/ha) was found at control treatment.

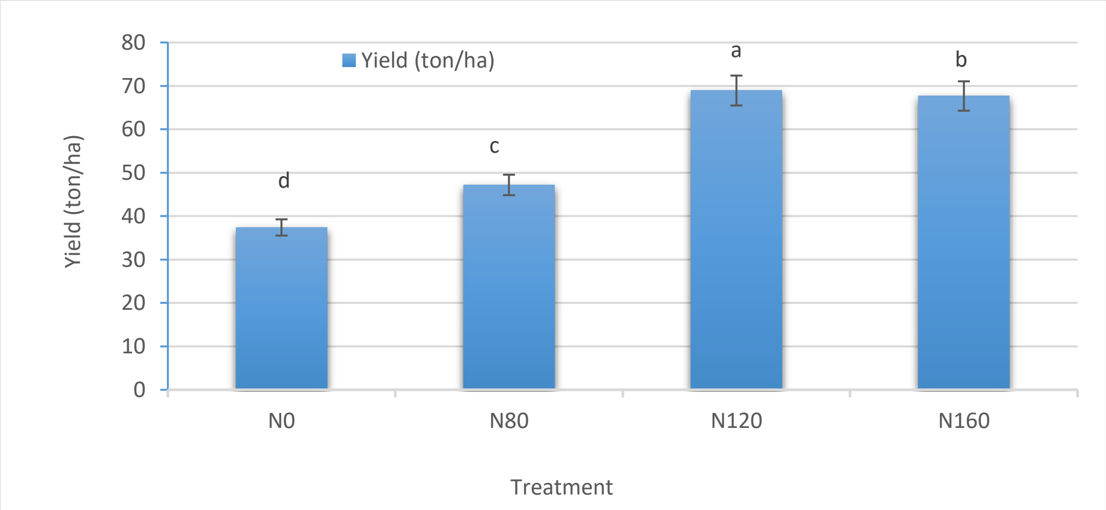

Figure 13. Effect of nitrogen on yield (ton/ha) of BARI Tomato-18

Table 10. Effect of nitrogen on yield parameter of tomato

Treatment	Fruit weight/plant (kg)	Fruit weight/plot (kg)	Fruit yield (ton/ha)	Fruit diameter in length (mm)	Fruit diameter in width (mm)
N_0	1.34 d	8.41 c	37.39 d	58.22 c	34.15 d
N_{80}	2.22 b	10.61 b	47.18 c	65.55 b	38.62 b
N_{120}	2.44 b	15.33 a	68.93 a	73.88 a	42.37 a
N_{160}	2.93 a	15.51 a	67.67 b	69.44 b	36.05 c
LSD $_{(O.05)}$	0.19	0.66	2.95	4.02	1.12
CV (%)	8.69	4.08	4.08	6.55	6.14

Table 11. Effects of boron on yield parameter of tomato

Treatment	Fruit weight/plant (kg)	Fruit weight/plot (kg)	Fruit yield (ton/ha)	Fruit diameter in length (mm)	Fruit diameter in width (mm)
B_0	2.094 b	11.74 c	52.21 c	65.08 a	37.25 b
$B_{1.0}$	2.262 a	13.12 a	58.35 a	67.25 a	38.35 a
$B_{1.5}$	2.351 a	12.53 b	55.72 b	65.08 a	37.80 ab
LSD $_{(O.05)}$	0.16	0.5749	2.5549	NS	0.97
CV (%)	8.69	4.08	4.08	6.55	6.14

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

B_0: 0 kg B/ha i.e. control $B_{1.0}$:1.0 kg B/ha $B_{1.5}$: 1.5 kg B/ha

Table 12. Combined effects of nitrogen and boron on yield parameter of tomato

Treatment	Fruit weight/plant (kg)	Fruit weight/plot (kg)	Fruit yield (ton/ha)	Fruit diameter in length (mm)	Fruit diameter in width (mm)
N_0B_0	1.21 f	7.71 j	34.5 j	53.66 f	33.86 ef
$N_0B_{1.0}$	1.42 f	8.43 ij	37.5 ij	60.00 ef	33.56 f
$N_0B_{1.5}$	1.38 f	9.09 hi	40.5 hi	61.00 e	35.03 ef
$N_{80}B_0$	1.81 e	9.76 h	43.5 h	63.00 de	34.50 ef
$N_{80}B_{1.0}$	2.27 d	10.68 g	47.65 g	63.66 cde	39.83 c
$N_{80}B_{1.5}$	2.59 bcd	11.38 fg	50.63 fg	70.00 abc	41.53 bc
$N_{120}B_0$	2.87 ab	12.12 f	54 f	72.66 ab	42.80 ab
$N_{120}B_{1.0}$	3.17 a	18.45 a	79.5 a	76.00 a	44.33 a
$N_{120}B_{1.5}$	2.75 bc	15.92 c	69.2 c	73.00 ab	40.00 c
$N_{160}B_0$	2.47 cd	17.37 b	75.75 b	71.00 ab	37.83 d
$N_{160}B_{1.0}$	2.53 cd	14.91 d	66.75 d	69.33 abcd	35.66 e
$N_{160}B_{1.5}$	2.31 d	13.74 e	61.1 e	68.00 bcd	34.66 ef
LSD $_{(O.05)}$	0.32	1.14	5.1099	6.97	1.94
CV (%)	8.69	4.08	4.08	6.55	6.14

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

N_0: 0 kg N/ha i.e. control N_{80}: 80 kg N/ha N_{120}: 120 kg N/ha N_{160}: 160 kg N/ha

B_0: 0 kg B/ha i.e. control $B_{1.0}$:1.0 kg B/ha $B_{1.5}$: 1.5 kg B/ha

The increasing level of boron increased the fruit yield per hectare significantly (Fig. 14). The application of boron 1.0 kg/ha i.e. $B_{1.0}$ treatment provided maximum yield of fruit per hectare (58.35 ton). The minimum yield per hectare (52.21 ton) was found at control treatment. This showed that application of higher amount of boron up to a certain level provided higher amount of yield of BARI tomato - 18.

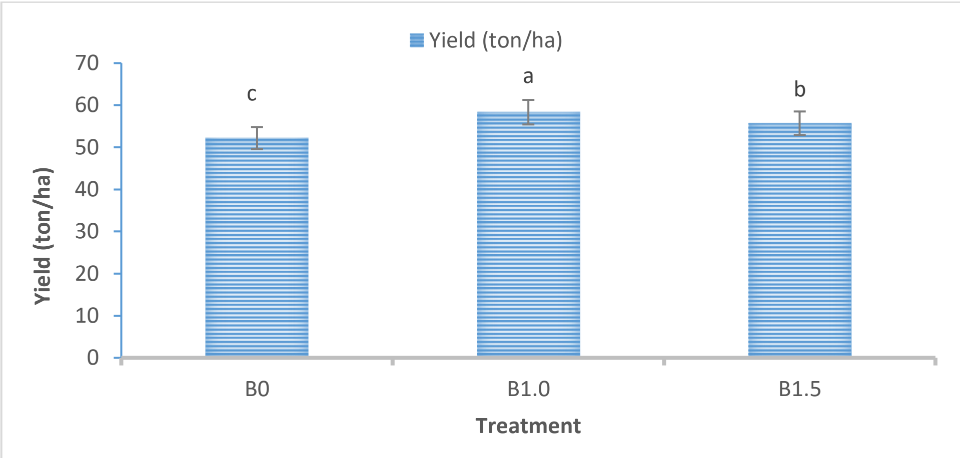

Figure 14. Effect of boron on yield (ton/ha) of BARI Tomato-18

The interaction effects of N and B on fruit yield were significantly influenced (Fig. 15). The treatment of $N_{120}B_{1.0}$ provided the highest number of fruit yield per hectare (79.5 ton). The lowest yield per hectare (34.5 ton) was found at control treatment.

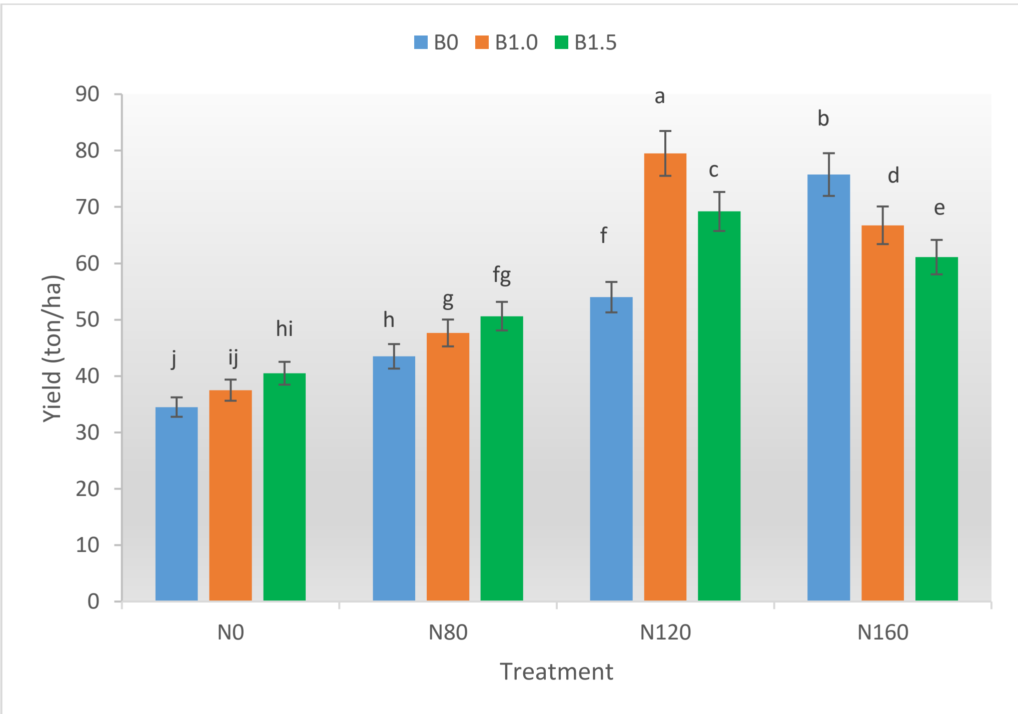

Figure 15. Interaction effect of nitrogen and boron on yield (ton/ha)

4.1.12 Fruit length (mm)

The length of fruit had significant variation due to the application of different levels of nitrogen (Table 10). The highest length of fruit (73.889 mm) was found at N_{120} treatment. The lowest length of fruit (58.222 mm) was recorded at control treatment.

The length of fruit had no significant variation due to using different level of boron (Table 11). The maximum and minimum length of fruit (67.250 mm) and (65.083 mm) was recorded at the treatment of $B_{1.0}$ and B_0 respectively which was statistically similar with one another.

The length of fruit had significant variation due to the application of different interaction levels of nitrogen and boron (Table 12). The maximum length of fruit (76.00 mm) was recorded from $N_{120}B_{1.0}$ treatment and the minimum length of fruit (53.667 mm) was recorded at control treatment.

4.1.13 Diameter of fruit (mm)

The diameter of fruit had significant variation due to application of different level of nitrogen (Table10). The maximum width of fruit (42.378 mm) was recorded at N_{120} treatment. The minimum width of fruit (34.156 mm) was found at control treatment. This showed that fruit diameter in width increased with increasing level of nitrogen up to 120 kg N/ha and addition of further nitrogen reduced the diameter of fruit.

There was significant variation on the diameter of fruit by using different level of boron (Table11). The highest and lowest width of fruit (38.350 mm) and (37.250 mm) was found at $B_{1.0}$ and control (B_0) treatments respectively.

The variation of width of fruit was significant by using different interaction level of nitrogen and boron (Table 12). The highest width of fruit (44.333 mm) was recorded at $N_{120}B_{1.0}$ treatment. The lowest width of fruit (33.567 mm) was recorded at $N_0B_{1.0}$ combination which was statistically close with N_0B_0 treatment.

4.2 Nutrient content in post-harvest soil

Nutrient such as N, P, S, K, pH, OC, OM content in soil was estimated for different level of nitrogen and boron application and also their different combination.

4.2.1 Nitrogen concentration in post-harvest soil of tomato field (%)

The effect of different doses of nitrogen fertilizer showed highly significant in variation of the nitrogen concentration in post-harvest soil (Table 13) of tomato field. The total N content of the post-harvest soil varied from 0.06% to 0.08%. Among the different doses of nitrogen fertilizer, N_{120} and N_{160} treatment showed the highest N concentration (0.08%) in post-harvest soil. The lowest value (0.06%) was observed under control treatment. The result revealed that application of increasing number of nitrogen increased the concentration of nitrogen in post-harvest soil.

The different doses of boron fertilizer had highly significant effect on nitrogen concentration in post-harvest soil (Table 14). The highest number of nitrogen concentration (0.07%) was found at $B_{1.5}$ treatment which was statistically similar with $B_{1.0}$ and the lowest was recorded at B_0 (0.06%) treatment.

The combination of nitrogen and boron had significant effect on nitrogen concentration in post-harvest soil (Table 15). The maximum nitrogen concentration (0.08 %) was observed at $N_{120}B_{1.5}$ treatment combination which was statistically close with $N_{160}B_{1.0,}$ $N_{160}B_{1.5}$ combinations. The minimum concentration of nitrogen (0.06 %) was observed at control treatment.

Table 13. Effect of nitrogen on the nitrogen, phosphorus, potassium, sulphur, pH, organic carbon, organic matter of tomato field

Treatment	%N	P(ppm)	K(meq/100g soil)	pH	S (ppm)	%OC	%OM
N_0	0.06	19.44	0.13	5.77	23.50	0.65	1.12
N_{80}	0.07	20.06	0.14	5.98	24.44	0.68	1.17
N_{120}	0.08	20.71	0.15	6.02	25.16	0.69	1.18
N_{160}	0.08	21.00	0.16	6.08	25.66	0.72	1.24
LSD $_{(O.05)}$	NS	NS	NS	NS	NS	NS	NS
CV (%)	8.72	3.75	4.84	1.88	2.41	12.10	12.10

Table 14. Effect of boron on the nitrogen, phosphorus, potassium, sulphur, pH, organic carbon, organic matter of tomato field

Treatment	%N	P (ppm)	K(meq/100g soil)	pH	S (ppm)	%OC	%OM
B_0	0.06	20.53	0.14	5.95	24.58	0.65	1.12
$B_{1.0}$	0.07	20.21	0.15	5.98	24.58	0.65	1.12
$B_{1.5}$	0.07	20.16	0.15	5.96	24.91	0.7	1.21
LSD $_{(O.05)}$	NS	NS	NS	NS	NS	NS	NS
CV (%)	8.72	3.75	4.84	1.88	2.41	12.10	12.10

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

B_0: 0 kg B/ha i.e. control $B_{1.0}$:1.0 kg B/ha $B_{1.5}$: 1.5 kg B/ha

Table 15. Interaction effect of nitrogen and boron on the nitrogen, phosphorus, potassium, sulphur, pH, organic carbon, organic matter of tomato field

Treatment	%N	P (ppm)	K (meq/100g soil)	pH	S (ppm)	%OC	%OM
N_0B_0	0.06	20.00	0.12	5.76	23.00	0.62	1.06
$N_0B_{1.0}$	0.06	19.00	0.14	5.80	23.50	0.63	1.08
$N_0B_{1.5}$	0.06	19.33	0.13	5.76	24.00	0.65	1.12
$N_{80}B_0$	0.06	20.16	0.14	5.90	24.50	0.66	1.13
$N_{80}B_{1.0}$	0.08	20.36	0.15	6.03	24.50	0.65	1.55
$N_{80}B_{1.5}$	0.07	19.66	0.15	6.03	24.33	0.68	1.17
$N_{120}B_0$	0.07	20.96	0.16	6.00	25.16	0.68	1.17
$N_{120}B_{1.0}$	0.08	20.83	0.15	6.06	24.66	0.7	1.20
$N_{120}B_{1.5}$	0.08	20.33	0.15	6.00	25.66	0.71	1.22
$N_{160}B_0$	0.07	21.00	0.16	6.16	25.66	0.72	1.24
$N_{160}B_{1.0}$	0.08	20.66	0.16	6.03	25.66	0.71	1.20
$N_{160}B_{1.5}$	0.08	21.33	0.17	6.06	25.66	0.72	1.24
LSD $_{(O.05)}$	NS	NS	NS	NS	NS	NS	NS
CV (%)	8.72	3.75	4.84	1.88	2.41	12.10	12.10

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

N_0: 0 kg N/ha i.e. control N_{80}: 80 kg N/ha N_{120}: 120 kg N/ha N_{160}: 160 kg N/ha

B_0: 0 kg B/ha i.e. control $B_{1.0}$:1.0 kg B/ha $B_{1.5}$: 1.5 kg B/ha

4.2.2 Phosphorus concentration in post-harvest soil (ppm)

The application of different level of nitrogen had highly significant variation on phosphorus concentration in post-harvest soil (Table 13). The highest phosphorus concentration (21.00 ppm) was found at N_{160} treatment and the lowest phosphorus concentration (19.44 ppm) was found at control treatment.

Different level of boron had no significant effect on phosphorus concentration in post-harvest soil (Table 14). The highest amount of phosphorus concentration (20.53 ppm) was found at B_0 treatment and the lowest phosphorus concentration (20.16 ppm) was found at $B_{1.5}$ treatment which was statistically similar.

Different interaction of nitrogen and boron had no significant effect on phosphorus concentration in post-harvest soil (Table 15). The maximum concentration of phosphorus (21.33 ppm) was recorded at $N_{160}B_{1.5}$ treatment and the minimum phosphorus concentration (19.00 ppm) was recorded at $N_0B_{1.0}$ treatment.

4.2.3 Potassium concentration in post-harvest soil (meq/100g soil)

Potassium concentration in post-harvest soil was not significant in variation due to different level of nitrogen (Table 13). The highest potassium concentration (0.16 meq/100g soil) was recorded at N_{160} treatment. The lowest concentration of potassium (0.13 meq/100g soil) was recorded at control condition.

Different level of boron had no significant effect on potassium concentration in post-harvest soil (Table 14). The maximum potassium concentration (0.15 meq/100 g soil) was recorded at $B_{1.0}$ and $B_{1.5}$ treatments and minimum concentration was found at B_0 (0.14 meq/100 g soil).

The interaction of nitrogen and boron had significant effect on potassium concentration in post-harvest soil (Table 15). The maximum concentration of potassium (0.17 meq/100g soil) was found at $N_{160}B_{1.5}$ treatment and the minimum concentration of potassium (0.12 meq/100 g soil) was recorded at control treatment.

4.2.4 pH value in post-harvest soil

The Variation of pH value was highly significant due to different level of nitrogen (Table 13). The maximum and minimum pH value in post-harvest soil (6.08) and (5.77) was recorded at N_{160} and control treatments respectively.

Different level of boron had no significant effect on soil pH (Table 14). The highest and lowest pH (5.98) and (5.95) was found at $B_{1.0}$ and B_0 treatments respectively which was statistically similar.

The interaction effect of nitrogen and boron had no significant effect on pH of post-harvest soil (Table 15). The maximum pH (6.16) was found at $N_{160}B_0$ treatment and minimum (5.76) was found at control treatment.

4.2.5 Sulphur concentration in post-harvest soil (ppm)

The variation of Sulphur concentration was highly significant by application of different level of nitrogen (Table 13). The highest amount of Sulphur (25.66 ppm) was found at N_{160} treatment. The lowest amount of Sulphur (23.50 ppm) was found at control treatment.

Different level of boron application had no significant effect on S concentration in post-harvest soil (Table 14). Highest concentration of S (24.91 ppm) was recorded at $B_{1.5}$ treatment and lowest (24.58 ppm) was recorded at B_0 treatment.

Different level of combination of nitrogen and boron was not significant in variation on S concentration (Table 15). Maximum amount of S concentration (25.66 ppm) was recorded at $N_{160}B_{1.5}$, $N_{160}B_{1.0}$, $N_{160}B_0$ and $N_{120}B_{1.5}$ treatments. The lowest amount of S (23.00 ppm) was found at control (N_0B_0) treatment.

4.2.6 Amount of organic carbon (%)

Different level of nitrogen had highly significant effect on amount of organic carbon in post-harvest soil (Table 13). Maximum OC (0.72 %) was recorded at N_{160} and the minimum concentration of OC (0.65 %) was recorded at control treatment.

The variation of organic carbon concentration on soil was significant due to different level of boron (Table 14). Highest (0.7 %) and lowest (0.65 %) was recorded at $B_{1.5}$ and B_0 treatments respectively.

The interaction of nitrogen and boron had no significant effect on organic carbon concentration (Table 15). The highest OC concentration (0.72%) was recorded at $N_{160}B_0$ and $N_{160}B_{1.5}$ treatments and lowest (0.62%) organic carbon concentration was recorded at control (N_0B_0) treatment.

4.2.7 Amount Organic matter (%)

Different level of nitrogen had highly significant variation on amount of organic matter in post-harvest soil (Table 13). The maximum (1.24%) and minimum (1.12%) amount of OM was recorded at N_{160} and control treatments respectively.

Different level of boron had significant variation on amount of organic matter in post-harvest soil (Table 14). The maximum (1.21%) and minimum (1.12%) amount of OM was recorded at $B_{1.5}$ and B_0 treatment respectively.

Different level of interaction of nitrogen and boron had no significant effect on amount of organic matter in post-harvest soil (Table 15). The maximum (1.24%) was recorded at $N_{160}B_0$ and $N_{160}B_{1.5}$ treatment and minimum (1.06%) amount of OM was recorded at N_0B_0 treatment.

CHAPTER V

SUMMARY AND CONCLUSION

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The present experiment was carried out at the farm of Sher-e-Bangla Agricultural University, Dhaka-1207 to find out the effect of nitrogen and boron on growth and yield of tomato during the period from November 2019 to March 2020. The experiments consisted with 12 treatment combinations, comprising four level of nitrogen (viz. 0, 80, 120, 160 kg N/ha designated as N_0, N_{80}, N_{120}, N_{160}) and three level of boron (viz. 0, 1.0, 1.5 kg B/ha designated as B_0, $B_{1.0}$, $B_{1.5}$). The combined effect and individual effects of nitrogen and boron on yield and yield contributing characters of tomato and chemical components of in post-harvest soil were studied.

The experiment was set up in Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 2.25 m^2 (1.8 m × 1.25 m). The treatments were distributed randomly at each block. Data on growth and yield parameters were recorded and analyzed statistically. The difference was evaluated by least Significant Different (LSD) test.

Plant characters were influenced by fertilization of nitrogen and boron at different levels. The individual and interaction effect of N and B on yield and yield contributing characters and nutrient content of soil was found positive.

Nitrogen had significant influence on the plant height, number of flower per plant and number of fruit per plant. The highest plant height (127.89 cm), number of flower clusters per plant (13) were obtained from N_{160} treatment and number of flowers per cluster (14.11), number of fruits per cluster (11.33), number of fruits per plant (62.66), minimum days after transplanting to first flowering (33.67 DAT), minimum days from transplanting to first fruiting (42.77 DAT), and minimum days to harvesting (91.67 DAT) were recorded at N_{120} treatment. It revealed that increasing level of nitrogen up to certain level increased number of flowers per cluster, fruits number and their clusters number per plant, but further application of nitrogen decreased them. Nitrogen had significant effect on yield of tomato. The highest fruit weight per plant (2.93 kg), fruit weight per plot (15.51 kg) was found at treatment of N_{160}. Fruit yield (68.93 ton/ha), fruit length (73.88 mm) and fruit diameter (42.37 mm) was recorded at N_{120} treatment i.e. the more nitrogen the more the yield of tomato. N had significant effect on total N, P, S, OC, OM, pH concentration in postharvest soil. Maximum S content (25.66 ppm), P content (21.00 ppm), K content (0.16 meq/100 g soil), pH (6.08), OC (0.72 %), and OM (1.24 %) were recorded at N_{160} treatment and N content (0.08 %) was recorded at N_{120} treatment which showed that increasing number of nitrogen application could improve soil fertility.

Different level of boron had significant effect on plant yield and yield contributing characters. The maximum plant height (105.58 cm), number of fruits per cluster (8.16), fruits per plant (50.58), minimum days from transplanting to first flowering (37.08 DAT), days to first fruiting (47.66 DAT), minimum days from transplanting to first harvesting (97.41 DAT) were found by using $B_{1.0}$ treatment which was 1.0 kg B/ha and number of flower clusters per plant (10.25), flowers per cluster (10.75) were recorded at $B_{1.5}$ treatment. The maximum yield per plant (2.35 kg) was found at $B_{1.5}$ treatment, and yield per plot (13.12 kg) and yield per ha (58.35 ton) was observed at treatment of $B_{1.0}$. Boron had significant effect on N, and non-significant effect on P, S, OC, OM, pH concentration in post-harvest soil. Highest N concentration (0.07 %), S content (24.91 ppm), OC (0.7 %) and OM (1.21 %) were found at treatment of $B_{1.5}$ and P (18.54 ppm), K (0.15 meq/100 g soil), pH (5.98), were found by applying $B_{1.0}$ treatment i.e. applying more boron improved soil fertility.

The interaction effect of nitrogen and boron had significant effect on plant height of tomato, number of flower cluster and fruit per plant, fruit and flower number per cluster. Maximum plant height (137.67 cm), flower clusters per plant (14.33), flowers per cluster (15.33), fruits per cluster (13.00), fruits per plant (68.66), minimum days after transplanting to first flowering (32.33 DAT), days of first fruiting (40.33 DAT), days of first harvesting (88.33 DAT) were found by application the combination of nitrogen @ 120 kg/ha and boron @ 1.0 kg/ha i.e. $N_{120}B_{1.0}$ treatment. The interaction of N and B had significant effect on yield per plant, yield per plot, yield per ha and maximum rate of them are (3.17 kg), (18.45 kg), and (79.5 ton) were found respectively at treatment condition of $N_{120}B_{1.0}$. Fruit length was not significant but diameter was significant by the interaction of N and B. The maximum fruit length (76.00 mm) and diameter (44.33 mm) were found at treatment $N_{120}B_{1.0}$. P, K, S, pH, OC, OM concentration of post-harvest soil was not significant by different level of interaction of N and B. The maximum N (0.08 %) was found at $N_{120}B_{1.5}$ treatment, P (21.33 ppm), K (0.17 meq/100 g soil) S (25.66 ppm), OC (0.72 %), OM (1.24 %) were recorded at $N_{160}B_{1.5}$ treatment. pH (6.16) was found at treatment of $N_{160}B_0$ treatment.

From the results of the study the following conclusion may be drawn –

1. Individual effect of nitrogen and boron and combined effect of N and B on yield and yield contributing characters of BARI Tomato -18 was found positive and significant.
2. Combined application of nitrogen @ 120 kg/ha and boron @ 1.0 kg/ha showed the best performance in respect of growth and yield contributes of BARI Tomato -18.

Considering the situation of the present experiment, further studies in different agro-ecological zones (AEZ) of Bangladesh with another level of nitrogen and boron fertilizer should be suggested for regional adaptability and confirmation of the present findings.

CHAPTER VI

REFERENCES

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CHAPTER VII

APPENDICES

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Appendix I. Monthly record of air temperature, rainfall, relative humidity, and sunshine of the experimental site during the period from November 2019 to March, 2020

Month ad year	Average air temperature (^{0}C)			Average relative humidity (%)	Total rainfall (mm)	Total Sunshine per day (hrs.)
	Maximum	Minimum	Mean			
November, 2019	29.6	19.2	24.4	53	34.4	8
December, 2019	26.4	14.1	20.25	50	12.8	9
January, 2020	25.4	12.7	19.05	46	7.7	9
February, 2020	28.1	15.5	21.8	37	28.9	8.1
March, 2020	32.5	20.4	26.45	38	65.8	7

Source: Bangladesh Meteorological Department (Climate & weather division), Dhaka

Appendix II. Analysis of variance of the data on plant height, number of flower clusters per plant, flowers per cluster, fruits per cluster, fruits per plant, and first flowering, fruiting, harvesting date

Source of variation	Degrees of freedom	Mean square						
		Plant height at harvest	No. of flower/ cluster	No. of fruit/ cluster	No. of fruits/ plant	1st flower -ing (DAT)	1st fruit-ing (DAT)	1st harvest -ing (DAT)
Replication	2	7	1.02	0.52	10.58	0.77	5.02	20.11
Nitrogen (N)	3	8334.2 **	86.33 **	95.48 **	1849.2 **	75.43 **	139.43 **	351.92 **
Boron (B)	2	688.58 **	3.02 **	6.02**	115.58 **	4.77 *	10.36 *	19.52 NS
Interaction (N×B)	6	324.40 **	3.13**	1.39**	94.58 **	13.18 **	20.99 **	32.56 *
Error	22	16.03	0.42	0.31	2.34	1.26	2.36	9.86

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

NS= Non-significant

Appendix III. Analysis of variance of the data on weight of fruits per plant, yield of tomato, length and diameter of tomato as influenced by nitrogen and boron

Source of variation	Degrees of freedom	Mean square				
		Fruit weight/plant (kg)	Yield (kg/plot)	Yield (ton/ha)	Fruit length (mm)	Diameter of fruit (mm)
Replication	2	0.031	0.006	0.11	4.69	3.00
Nitrogen (N)	3	3.96**	199.38**	3938.39**	397.11**	113.87**
Boron (B)	2	0.20*	10.23**	202.17**	27.52 NS	3.63 NS
Interaction (N×B)	6	0.15**	22.71**	448.73**	27.19 NS	20.30**
Error	22	0.03	0.46	9.11	16.96	1.31

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

NS= Non-significant

Appendix IV. Analysis of variance of the data on nitrogen, phosphorus, potassium, Sulphur, organic carbon, organic matter and pH in post-harvest soil

Source of variation	Degrees of freedom	Mean square						
		%N	P (ppm)	K(meq/ 100g soil)	S(ppm)	%OC	%OM	pH
Replication	2	1.02	0.36	1.44	0.44	0.04	0.13	0.007
Nitrogen (N)	3	6.74 **	4.33 **	1.63 NS	7.97 **	0.20 **	0.61 **	0.16 **
Boron (B)	2	2.52 **	0.47 NS	3.61 NS	0.44 NS	0.07 *	0.23 *	0.002 NS
Interaction (N×B)	6	3.79 **	0.45 NS	8.79 **	0.36 NS	0.00 NS	0.02 NS	0.01 NS
Error	22	0.21	0.57	1.35	0.35	0.01	0.04	0.01

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


Appendix Figure I. Tomato seedling for the experiments


Appendix Figure II. Presentation of experimental field

Appendix Figure III. Fruits per plant of the experimental plot

Appendix Figure IV. Green and ripe tomato from experimental plot

Appendix Figure V. Some pictures of soil test at Soil Science Laboratory in Sher-e-Bangla Agricultural University