EFFECT OF VARIETY AND SPACING ON GROWTH AND YIELD OF TOMATO

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CERTIFICATE

This is to certify that thesis entitled, **"EFFECT OF VARIETY AND SPACING ON GROWTH AND YIELD OF TOMATO"** 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 **AGRICULTURAL BOTANY,** embodies the result of a piece of bonafide research work carried out by **TOUHIDA KHATUN, Registration No. 10-03988** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2017
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DEDICATED TO
MY
BELOVED PARENTS

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ABSTRACT

A field experiment on tomato (*Solanum lycopersicon* L.) was conducted at the Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during October, 2015 to April 2016 to find out the suitable varieties and spacing for higher yield of the crop. Ten treatment combinations consisting of five tomato varieties, namely Soysan, Unnayan, Minto hybrid, Ratan, Holand and two spacing *viz.*, 50 cm × 40 cm and 60 cm × 40 cm were tested in Randomized complete Block Design (RCBD) with three replications. The variety Minto hybrid exhibited the maximum plant height, leaves plant^{-1}, primary and secondary branches plant^{-1}, flower cluster^{-1}, fruit plant^{-1}, fruits cluster^{-1}, fruit length, fruit breath and individual fruit weight. The highest fruit yield (34.30 t ha^{-1}) was obtained from Minto hybrid followed by Ratan (17.72 t ha^{-1}). Different parameters studied were not significantly influenced by two spacing. However, the wider spacing 60 cm × 40 cm gave the maximum fruit yield (39.92 t ha^{-1}). The Minto hybrid coupled with 60 cm × 40 cm spacing gave maximum values in all growth parameters and yield attributes, and thus provided the highest fruit yield (70.26 t ha^{-1}). The second highest fruit yield (66.96 t ha^{-1}) was recorded from Minto hybrid coupled with 50 cm × 40 cm.

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LIST OF ABBREVIATION AND ACRONYMS

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

CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) belongs to the Solanaceae family and self-crossing annual crop. This family includes many other well known crops such as potato, tobacco, hot pepper and eggplant (Seid *et al.*, 2013). Tomato is a very important vegetable cultivated and consumed in most parts of the world, from home gardens and greenhouses to large commercial farms due to its wider adaptability to various agro-climatic conditions (Agyeman *et al.,* 2014). It is one of the important, popular and nutritious vegetable grown in Bangladesh usually in winter season and cultivated in all parts of the country (Haque *et al.,* 1999).It is grown on more than 5 million ha with a production of nearly 129 million tons. China is the world's top tomato grower, accounting for more than one-quarter of the world's tomato acreage. Egypt and India together account for more than one-fifth of the world total; Turkey and Nigeria are the other major tomato producing countries. Asia and Africa account for about 79 percent of the global tomato area, with about 65 percent of world output (FAO, 2008). As it is a relatively short duration crop and gives high yield, so it is economically attractive and the area under cultivation is increasing daily all over the world (Bagal *et al.* 1989).

Tomato is widely used as salad as well as for cooking purposes. It is well known for its nutritional importance as it is the rich source of nutrients Na, K, Fe, vitamin A and C and antioxidants especially lycopene and salicylate (Afzal *et al.,* 2013). Lycopene is an antioxidant which protects the cells from oxidative damage, so it decreases the risk of chronic diseases such as coronary heart diseases and cancer diseases (Giovannucci, 2002, Taber *et al*., 2008). The mode of action is tentative, but they are believed to reduce cancer risk by successfully trapping oxygen and intermediates of free oxygen radical. Lycopene is soluble in fat and it is the precursor of β-carotene. It has at least two folds antioxidant capacity of β-carotene (Taber *et al*. 2008). Lycopene concentration in tomato fruit depends upon maturity, genetics, environmental conditions, cultivation techniques and production methods. The environmental conditions like temperature, light, fertility and others affect fruit lycopene (Robertson, 1995; Kanai *et al*., 2007).

The importance of tomato as a vegetable crop is reflected in its large-scale cultivation in the world. Tomato is grown on about 4.5 million hectares worldwide, the largest producer being China with 32 million metric tons. India produces about 7.6 million metric tons of tomatoes from about 540,000 ha (Daniel, 2007). Now-a-days tomato is grown in most of the countries around the globe except the cooler region. It can be grown on a small scale in the kitchen garden, where a few plants yielding fruits for the whole family and a commercial scale as a cash crop by the vegetable growers (David, 2010). In Bangladesh, it is cultivated as winter vegetables, which occupied on area of 59000 acres of land, and the total production of tomatoes were 255 thousands metric tons in Bangladesh in the year of 2011-2012 (BBS, 2014). Thus the average yield of tomato is 14.35 tons/ha, while it was 41.81 t/ha in the world (FAO, 2007),which is very low in comparison with that of other countries, namely India (15.67 t/ha), Japan (52.82 t/ha) and USA (63.66 t/ha).The yield of tomato in our country is not satisfactory enough in comparison to requirement (Aditya *et al.*, 1999).

It has been reported that variety is an important factor, which greatly influenced the growth and yield of tomato. Previous many reports states that variety influences growth, yield contributing characters and yield of tomato (Ahmed *et al*., 1986; Kalloo, 1989; Thomas *et al.,* 1979).

The national average of tomato fruit yield under farmers' condition is 9 t/ha, which is very low compared to 25 and 40 t/ha at demonstration and experimental research plots, respectively (Lemma, 2002). Increasing production of the crop has a great role to strengthen the growing vegetable industries in the country. However, the production and productivity of the crop in the country is influenced by different factors. Lemma *et al.* (2003) reported that plant spacing greatly influenced fruit yield in both fresh market and processing tomatoes. Mehla *et al*. (2000) also reported the importance of plant spacing on yield and quality parameters in tomato crop.

At present farmers are getting low tomato yield mainly due to inappropriate management practices and lack of improved variety. Improper plant spacing is among the notable reasons of low productivity of tomato.

Considering the above mentioned issues, the present experiment was conducted with the following objectives.

i. To observe the effect of variety and spacing on growth of tomato plants.
ii. To find out the suitable variety for higher yield of tomato
iii. To determine the suitable plant spacing for higher yield of tomato.

CHAPTER II

REVIEW OF LITERATURE

Tomato is an important vegetable crop and received much attention of the researchers throughout the world to develop its suitable production technique. Establishment and growth of tomato plants largely depend on the variety and spacing. Large number of researchers has studied the effect of variety and spacing on the growth, yield and yield attributes of tomato in different countries of the world. However, literature is available in this respect at home and abroad has been reviewed here, which will contribute useful information to the present study.

2.2 Effect of variety on growth and yield of tomato

Hamid*et al.* (2005) carried out an experiment to study the performance of five Russian (‘Raickoi Naclazdenie’, ‘BelaiNalev’, ‘Ceberckoi Ckorocpelai’, ‘Novichok’, ‘Patris’) and one local variety of tomato under Rawalakot conditions during the year 2003. The results indicated that maximum plant height and size of fruit were observed in variety ‘Raickoi Naclazdenie’, whereas maximum number of flower clusters and fruits per plant were observed in 'Patris'. Minimum plant height, number of flower clusters and fruits were noted in Novichok, whereas minimum number of branches and fruit weight/plant was noted in Local ‘Kashmir’. Varieties ‘Ceberckoic Ckorocepali’ and ‘Patris’ gave maximum fruit weight of 4.96 and 4.85 kg/plant compared to the minimum of 1.60 kg/plant by local check and ‘Novichok’. Exotic varieties ‘Patris’ and ‘Ceberckoi Ckorocpali’ are recommended for commercial cultivation due to high production.

Khalid (1999) conducted an experiment with two winter (Ratan and Bahar) and three summer (BINA Tomato-2, BINA Tomato-3 and E-6) varieties of tomato during the winter season of 1998-99 at the Horticulture farm, BAU, Mymensingh. He observed that the highest yield/plant was obtained from BINA Tomato-2 (1.74 kg), followed by BINA Tomato-3 (1.67 kg). But the yields of these varieties were statistically similar to each other.

Singh and Sahu (1998) conducted a field experiment at Keonjhar, Orissa, India during rabi 1991-92 and 1992-93 to evaluate 23 tomato cultivars to find out a suitable variety for winter season cultivation. They reported that 'BT 12' produced the highest yield (34.09 t/ha) closely followed by 'BT17', 'PED', 'BT14', 'Sel 120', 'BT1' and 'Punjab Chhuhara'. The variety 'Sel 120' had the highest weight and girth of fruit, whereas 'Punjab chhuhara' produced the maximum number of fruits/plant and took less time to mature. The variety 'Arka Alok' was the earliest and had large fruits. 'Marglobe' had the maximum vegetative growth.

A field trial was conducted in Jordan during 1993 to study the yield of 13 local and introduced open pollinated tomato cultivars, and to compare the yields to that of 3 common hybrids (Maisara F_1, 898 F_1 and GS12F_1) in relation to seasonal distribution of marketable and unmarketable yield and fruit number. The cultivars varied in their marketable yield during the harvested period (10 weeks from 22 June 1993). The results indicated that the cultivars Rio Grande, Nagina and T_2 improved were superior to the hybrids (Ajlouni *et al.,* 1996).

An experiment was conducted at Wooster, USA with the hybrid processing tomato Ohio Ox 38 (Berry *et al*, 1995). It was observed that the yields of this variety in 1992 and 1993 were higher (70.3 and 80.4 t/ha, respectively) compared to other cultivars.

Bhangu and Singh (1993) conducted a field trial with some tomato cultivars (Punjab Kesari, Punjab Chhuhara, Punjab Tropic, PNR-7, S-12, Pusa Ruby and the Hybrid THL-2312) in 1990 and 1992. Mean annual yield was highest in Punjab Kesari and lowest in Punjab Tropic. The number of fruits per plant was highest in Punjab Kesari (123). Punjab Tropic produced the largest fruits (66.69g).

Kalloo (1989) worked with some tomato varieties (Pusa Early Dwarf, HS 102, Hisar Arun (Sel 7) and Punjab Chhuhara) in northern India, he reported that HS102 and Punjab Chhuhara were fit for summer cultivation, and Pusa Early Dwarf and Hisar Arun were suitable for getting early fruits.

Ahmed *et al*. (1986) assessed eight F-7 lines of tomato at the Horticulture Farm, Bangladesh Agricultural University, Mymensingh. All the lines had shown identical results in plant height and fruit size. In contrast, fruit number had shown significant difference among the varieties. The line 0014-60-3-9-1-0 gave the highest yield of fruit (56.9 t/ha), followed by 0013-52-10-27-32-0 (50.0 t/ha).

An experiment was carried out under a BARC financed project BVRD, at its Joydebpur Sub-Centre, Gazipur during the summer season of 1976 with three tomato varieties. It was found that, the variety Hope-1 was more adapted to our summer climate than the other two. Although Hope-1 produced smaller fruits, it produced the highest number of fruits (16) per plant, as well as the highest yield (9.24 t/ha), indicating that the variety could tolerate heat and high humidity of Bangladesh better than the other two varieties (Hossain and Haque, 1984).

2.2. Effect of spacing on the growth and yield of tomato

Tuan and Mao (2015) conducted an experiment to evaluate the planting density on growth and yield of tomato fruit to determine the optimum planting density. Plant height, number of leaves per plant, fruit set, number of fruits per plant, fruit weight and fruit yield were recorded. Results indicated that treatment with 35714 plants per hectare had the highest plant height, whereas 25974 plants per hectare gave the lowest plant height. Moreover, 25974 plants per hectare had the best results in fruit set, fruit number as well as fruit weight. Planting density with 25974 plants per hectare gave the maximum fruit yield than the other treatments. It was concluded that 25974 plants per hectare significantly improved fruit growth and yield of tomato under field condition.

Ogundare *et al*. (2015) investigated the effect of different spacing and urea application rates on fruit nutrient composition, growth and fruit yield of tomato in derived savanna vegetation of Nigeria. The row spacing were 75 cm × 40 cm (33,333 plant ha^{-1}), 75 cm × 50 cm (26,666 plant ha^{-1}) and 75 cm × 60 cm (22,222 plants ha^{-1}) while the urea rates comprised control (0 kg urea ha^{-1}), 54.3 and 108.6 kg urea per hectare. Growth and yield parameters taken were as follows: average plant height, stem girth, leaf area (m^2) and yield per land area. The result obtained from this study indicated that urea application and spacing affected significantly growth parameters of tomato and yield per land area. Row spacing of 75 cm × 50 cm showed better performance in number of fruits and fruit yield per plot. Farmers in Ejiba and Kabba should apply urea at the rate of 54.8 kg per hectare and plant the crop at a row spacing of 75 cm × 50 cm for optimum yield and for a more profitable production of tomato.

Abrha *et al*. (2015) conducted an experiment at Tumuga and Fala locations during 2012/2013 cropping season under irrigated condition. The treatment consisted of factorial combination of two inter-row spacings (50 cm and 100 cm) and three intra-row spacing (20 cm, 30 cm and 40 cm) using Randomized Complete Block Design in a factorial arrangement (2 x 3) with three replications. The highest total and marketable fruit yield was obtained from 20 cm intra-row spacing with 50 cm inter row spacing. On the other hand, the lowest total and marketable fruit yield was obtained from the wider spacing of 40 cm intra-row with 100 cm inter-row spacing. Thus, Tomato (Roma VF variety) growers around the study area can be benefited if they use narrow spacing (20 cm intra and with 50 cm inter-row spacing).

Kirimi *et al.* (2011) investigated the effects of nitrogen levels and spacing on tomato fruit yield and quality in a Quonset greenhouse at 2238m above sea level. Spacing was 40 cm x 30 cm, 40 cm x 40 cm, 50 cm x 30 cm and 50 cm x 40 cm. Fruit yield and quality data were taken after each harvesting. Number of marketable fruits was significantly affected by spacing in both seasons. Nitrogen of 80 kg ha^{-1} and spacing of 40 cm x 30 cm had the highest mean fruit numbers in season 2. Nitrogen of 80 kg N ha^{-1} and spacing of 50 cm x 30 cm had the highest fruit yield in season 1. Marketable unit fruit weight was highest in season 1, at 50 cm x 40 cm. The study was significant to farmers producing tomatoes under greenhouse, to maximize on profits by scaling down nitrogen fertilizer use to attain high yields and quality of marketable tomato fruits using appropriate spacing.

Muhammad and Singh (2007) carried out an experiment at the Usmanu Danfodiyo University Fadama Teaching and Research Farm, Sokoto, during 2004/05 and 2005/06 dry seasons. Treatments consisted of factorial combination of two levels of training (staked and unstaked) and three levels pruning (three-stem, two-stem and unpruned) and three levels of intra-row spacing (20, 40 and 60 cm) laid out in a split-plot design replicated three times, with training allocated to the main plots and pruning intra-row spacing to the sub-plots. Results revealed that mean fruit length and diameter in the first trial, fruit weight in both trials and the two trials combined, total fresh fruit yield in the first trial and combined and percentage marketable yield in the first trial and the combined were significantly ($p<0.05$) higher in the tomato plants that were staked. Results on pruning showed that mean fruit length, diameter and weight in both trials were significantly higher in three-stem and two-stem pruned plants than unpruned plants. Similarly, three-stem pruned plant produced the highest total fresh fruit yield in both trials. Significant training x pruning interactions recorded, showed that the highest percentage marketable yield was at staked and pruned (both three and two-stem) plants; while two-stem with staking or no staking produced the highest mean fruit weight.

Kumar and Khanna (2006) conducted an experiment in Solan, Himachal Pradesh, India, in 2002 to evaluate the most suitable tomato transplant spacing and planting date at a field site infested with M. incognita. Tomatoes were transplanted on the 20th of each month from March through July and, on each dates, transplants were spaced 35, 45 and 55 cm apart in 60-cm-wide rows. The tomatoes transplanted in July suffered nematode damage in the vegetative phase and the cool temperatures at fruiting reduced ripening. The highest yield and largest fruit size were attained at the in-row plant spacing of 45 cm.

Carvalho and Tessarioli-Neto (2005) conducted an experiment to investigate the effects of plant spacing and number of branches per plant on fruit production in various tomato hybrids grown in a protected environment was studied. The treatments consisted of 4 hybrids (Andrea, Debora Max, Carmen and Diana), 2 spacing between plants (0.30 and 0.45 m) and 2 training systems (1 and 2 branches per plant). The treatments were replicated 4 times. The following parameters were studied: marketable yield (number of fruits per plant), total marketable yield, average weight of marketable fruits, and yield of big, medium and small fruits. A spacing of 0.30 m between plants and one branch per plant were the best combinations for Debora Max, which showed the highest yield potential.

Seedlings of cherry tomato were raised in August 2002 in soilless media under greenhouse conditions and 30-day-old seedlings were transplanted on 1 September 2002 at 3 plant spacing (60 cm x 30 cm, 60 cm x 60 cm and 60 cm x 90 cm) under drip fertigation system. Training of plants was performed in two systems, i.e. single main stem on each plant and two main stems on each plants. Plants of all treatments were trained and pruned regularly by removing the lateral branches from the leaf axils. Harvesting of fruits was started from the second week of November 2002 and continued up to the end of June 2003. A significant difference was observed between different treatments for number of fruit trusses per plant, average fruit weight and fruit yield of cherry tomato, but plant height was not influenced significantly by the different levels of plant spacing, stem pruning and training. The highest number of fruit-bearing trusses (30.33/plant) was recorded under the widest spacing with two main stems on each plant, while the greatest average fruit weight (10.1 g/fruit) was recorded when the crop was planted at the widest spacing with single main stem on each plant. Although, the highest fruit yield per plant (5.1 kg/plant) was obtained from plants with two main stems on each plant adjusted at the widest spacing, the highest fruit yield per ha (912.0 q/ha) was obtained when the cherry tomato plants with two main stems were grown at the closest spacing for long duration under semi-controlled greenhouse conditions of Delhi (India) (Balraj Singh and Mahesh Kumar 2005).

Thakur and Spehia (2005) conducted an experiment on the effect of drip lateral spacing and crop geometry on the yield and quality of tomato was investigated during May 1998 to August 2000 in Himachal Pradesh, India. The treatments included drip lateral distances of 1.80, 2.20, 2.60 and 3.00 m with varying plant to plant and row to row spacing: normal planting with spacing of 90 cm x30 cm; 4 rows of planting along each drip lateral (paired row planting with inter-pair spacing of 40 cm and plant spacing of 20 cm x 41cm or 20 cm x 36 cm within rows); 3 rows of planting along each drip lateral with spacing of 20 cm x 45 cm, 20 cm x 36 cm, 20 cm x 31 cm and 20 cm x 27 cm. The highest fruit yield (417.92 q/ha), the highest fruit number (31 fruits/plant), highest fruit diameter (48.83 mm), fruit weight (69.27 g) and best cost economics (5.13) were obtained under drip lateral spacing of 2.60 m, with 4 rows of planting along each lateral at 40 cm inter-pair spacing and a spacing of 20 cm x 41 cm within rows.

Ahmad and Singh (2005) conducted an experiment at the Usmanu Danfodiyo University Teaching and Research Fadama Farm, Sokoto, with the objective of evaluating the effects of staking and spacing on Roma VF cultivar of tomato. Treatments consisted of factorial combinations of four rows spacing (40, 60, 80 and 100 cm) and two staking (staked and unstaked). Plants with a row-spacing of 100 cm recorded significantly higher mean fruit weight (188 g) and diameter (5.48 cm) than other row spacing. However, total fresh tomato yield was significantly influenced by a row-spacing of 40 cm (53.98 t ha^{-1}) than 60 (45.7 t ha^{-1}), 80 (37.1 t ha^{-1}) and 100 cm (32.7 t ha^{-1}). From this study, it was concluded that even though the fruit size and the weight was higher in wider spaced rows, the total yield obtained was higher in the close spaced rows.

Singh (2005) conducted during 1997-98, in Bichpuri, Agra, Uttar Pradesh, India, to evaluate the effects of spacing (75 cm x50 cm, 75 cm x75 cm and 75 cm x100 cm) and nitrogen level (0, 75, 150, 200 and 250 kg/ha) on tomato hybrid Naveen. Data were recorded for plant height, number of laterals per plant, weight per fruit, diameter of fruit, number of fruits per plant, weight of fruits per plant and fruit yield. The highest yield was obtained with the narrowest spacing and highest nitrogen fertilizer level.

The effects of spacing (45 cm x 30 cm, S_1; 60 cm x 30 cm, S_2; 90 cm x 30 cm, S_3; and 120 cm x30 cm, S_4) and training system (single leader, T_1; double leader, T_2; and triple stem, T_3) on the performance of tomato (*cv*. Naveen-2000) were studied in Nauni, Solan, Himachal Pradesh, India, during 1997-98. T_1 resulted in the lowest number of days to first picking (72.10), and greatest fruit weight (84.27 g) and plant height (247.25 cm). The number of fruits per plant (19.57), yield per plant (1.20 kg) and yield/ha (505.80 quintal) were greatest under T_2. The highest ascorbic acid content (31.34 mg/100 g) and TSS [total soluble solids] (4.29 degrees Brix) were recorded for the unpruned control. S_4 registered the lowest number of days to first picking (72.92), and greatest fruit weight (79.56 g), whereas S_3 recorded the highest number of fruits per plant (20.67) and yield per plant (1.25 q.). Plant height was greatest under S_1 (205.50 cm) and S_2 (205.00 cm). The ascorbic acid content was highest under S_1 (31.15 mg/100 g). S_3 and S_4 gave the highest TSS (4.15 and 4.33 degrees Brix). T_3 + S_2 recorded the highest number of fruits per cluster (3.87). The number of fruits per plant was highest for plants under T2 + S_2 (22.43) and unpruned plants under S_3 (23.60). Yield per plant (1.35 kg) and per hectare (675.0 quintal), net return (201 503.45 rupees) and cost benefit ratio (1:2.94) were highest under T_2 + S_2. T_1 + S_4 gave the tallest plants (256.0 cm). Fruits of unpruned plants under S_1 had the highest ascorbic acid content (32.42 mg/100 g). TSS was highest for unpruned plants under S_3 (4.37 degrees Brix) and S_4 (4.76 degrees Brix). (Thakur *et al*., 2005).

The response of tomato *cv.* Arka Alok to plant spacing (50 cm x 30 cm, 50 cm x 45 cm or 50 cm x 60 cm), and N (50, 75, 100 or 125 kg/ha) and P (25, 50 or 75 kg/ha) rates was studied by Singh (2003) in Ranchi, Bihar, India during the rainy season. P was applied, along with 1/3 of N, one day before transplanting. The remaining N was applied at 25 days after transplanting. Spacing did not significantly affect yield and number of fruits per plant, plant height, survival and fruit quality parameters (weight, total soluble solid content and firmness). The highest number of marketable fruits ($32.3m^{-2}$) and total yield (243.67 q/ha) were obtained with a spacing of 50 cm x30 cm. P and N did not significantly affect the aforementioned parameters except survival at the last harvest, which was highest (67.8%) with 75 kg N/ha..

Singh *et al.* (2002) conducted an experiment in Agra, Uttar Pradesh, India during the rabi season of 1996-99 to determine the effects of different N rates (0, 100, 200 and 300 kg/ha) and plant spacing (75 cm x 50 cm, 75 cm x 75 cm and 75 cm x 100 cm) on the yield and yield attributes of tomato cultivars Naveen (indeterminate) and Rupali (determinate). The number of fruits per plant; fruit weight, diameter and specific gravity; fruit yield per plant; and total yield increased with increasing plant spacing and N rates up to 200 kg/ha, and decreased thereafter.

Tomato *cv.* Hisar Lalit seeds were sown at 60 cm x 30cm, 60 cm x 45 cm and 60 cm x 60 cm spacing (one-sided planting) or at 120 cm x 30 cm, 120 cm x45 cm or 120 cm x 60 cm spacing (two-sided planting), and supplied with 80, 120 or 180 kg N/ha in a field experiment conducted in Hisar, Haryana, India during the spring and summer season of 2000. Seed yield per plant and per hectare increased with increasing rates of N. Significant difference in the seed recovery, test weight and vigour due to N rates were not observed. Two-sided planting resulted in higher seed yield per plant and per hectare, and seed vigour. The interaction effects of N and method of planting on the germination of tomato were significant, with two-sided planting at 120 cm x45 cm spacing and application of 100 kg N/ha results the highest seed germination (Janardan- Ghimire *et al.* 2002).

Sharma *et al.* (2001) conducted an experiment in Kullu, Himachal Pradesh, India, during 1996 and 997 to study the effect of N (0, 50, 100, 150, and 200 kg/ha) and spacing (60 cm x 30 cm, 60 cm x 45cm, and 60 cm x 60 cm) on the growth and yield of tomato. One-third of the total N was applied basally while the remaining two-thirds were applied at 30 days after transplanting ad at fruit initiation stage. Fruit and seed yields, number of fruits per plant, plant height, fruit length, fruit diameter, and fruit weight increased with the increase in N rate. However, yields produced with 150 and 200 kg N/ha did not significantly vary. The increase in N rate delayed maturity. The widest spacing (60 cm x 60 cm) gave the highest fruit and seed yields per plant, number of fruits per plant, and fruit weight. However, 60 cm x 45 cm resulted in the highest fruit and seed yields per ha. Based on the overall effect, 150 kg N/ha and a spacing of 60 cm x45 cm were best for optimum tomato yields.

Adpawar *et al.* (2000) conducted an experiment in Akola, Maharashtra, India, during kharif 1996-97 to study the effects of plant distance (30, 45, 60, and 75 cm) and staking (single wire, double wire, and single plant stakes) on the growth, yield-contributing characters, and quality of tomato *cv*. Dhanshree. Row distance was maintained at 45 cm. Staking was conducted at 30 days after transplanting. At 120 days after transplanting, plant height, nodal distance, and yield per plot increased with closer spacing while the number of branches, number of flower clusters per plant, number of fruits per plant, number of fruits per cluster, fruit weight, yield per plant and hectare, fruit length and breadth, total soluble solids, juice content, and acidity increased with wider spacing. Early flowering and harvesting were also obtained with closer plant distance.

Mohamed (1999) conducted an experiment during the winter seasons of 1995 and 1996 to different plant spacing (1.00 and 1.15 m between rows in combination with 0.4 and 0.8 m between plants) and nitrogen levels (10, 20, 30 and 40 kg/Doanum). Data were recorded for plant height, stem thickness, fruit yield, and fruit characteristics. Plant height and stem thickness increased with increasing plant spacing in both seasons. Total and early yield decreased with decreasing plant spacing. The highest yield was obtained at 1 mx0.8 m spacing. Nitrogen at 20 kg/Doanum was the best treatment in enhancing the growth and yield of tomato. Fruit weight decreased with closer spacing and lower nitrogen rates in both seasons.

2.3 Interaction effect of variety and spacing of the growth and yield of tomato.

Balemi (2008) conducted an experiment on vertisol at Ambo University College (Ethiopia) during 2003/2004 and 2004/2005 cropping seasons to investigate the response of tomato cultivars varying in growth habit to rates of Nitrogen (N) and Phosphorus (P) fertilizers and plant spacing. Besides the main factors effect, fertilizer rate × spacing and cultivar × spacing interaction effects were also observed on % marketable fruit yield and 10 fruit weight, respectively. The results of 2003/2004 cropping season showed 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. Result of 2004/2005 cropping season, however, demonstrated that only the application the highest fertilizer rate (110 kg N + 120 kg P_2O_5/ha) resulted in superior fruit yields whilst the other two rates did not significantly differ from each other in affecting fruit yields. Results of both cropping seasons confirmed significantly higher % marketable fruit yield due to the application of either 110 kg N + 120 kg P_2O_5/ha or 80 kg N + 90 kg P2O5/ha. Closer spacing of 80 cm x 30 cm and 60 cm x 45 cm gave higher total as well as marketable fruit yield than the wider spacing of 100 cm x 30 cm.

The effects of spacing (50 cm x 40 cm and 40 cm x 30 cm) on the fruit yield and quality of tomato cultivars Maskotka, Ola, and Pinokio were studied in Szczecin, Poland, during 1998-2000. The increase in crop density resulted in the increase in total, commercial, and first-class yields. The yields of Maskotka and Ola were higher by 0.97 kg m-2 than those of Pinokio. Ola produced the heaviest (53.2 g) and largest (45.6 mm in diameter) fruits with the thickest pericarp (5.71 mm). The highest soluble solid (7.90%), dry matter (9.06%), sugar (4.96%), and vitamin C [ascorbic acid] (33.5 mg) contents were recorded for Pinokio. Maskotka fruits had the highest organic acid content. Storage quality and weight loss were also evaluated in fruits stored for 1, 2, 3, or 4 weeks in a cold chamber (12 degrees C). Both parameters significantly decreased with increasing storage period. After 4 weeks, the fruits recorded a weight loss of 90.9%. Pinokio fruits were characterized by lower weight reduction and better storage quality than Maskotka and Ola fruits (Dobromilska, 2002).

Mehla*et al.* (2000) conducted to the response of 3 tomato cultivars (Hisar Lalima, Hisar Anmol and Hisar Arun) to 3 levels of N and P fertilizers (50 kg N/ha + 30 kg P/ha, 100 kg N/ha + 60 kg P/ha and 150 kg N/ha + 90 kg P/ha) and 4 spacing (60 cm x 60 cm, 60 cm x 45 cm, 45 cm x 45 cm and 30 cm x 30 cm) was investigated during 1992 and 1993 in Haryana, India. Among the cultivars, Hisar Arun gave the highest values for all parameters studied, including the highest total fruit yields of 403.3 and 360.4 q/ha during 1992 and 1993, respectively. All yield parameters, except fruit size, increased with wider spacing. Among the different treatments, the 45 cm x 45 cm spacing was found optimum, as it gave high values for all yield parameters. Hisar Arun planted at a 30 cm x 30 cm spacing gave the highest early (325.6 and 271.9 q/ha) and total fruit yield (453.0 and 398.9 q/ha) during 1992 and 1993, respectively. Similarly, the highest fertilizer levels coupled with the closest spacing gave the highest early (283.0 and 255.5 q/ha) and total fruit yield (453.5 and 413.2 q/ha) during 1992 and 1993, respectively.

CHAPTER III

MATERIALS AND METHODS

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

3.1. Location of the experiment field

The field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh from October, 2015 to April2016to evaluate the effect of variety and spacing on growth and yield of tomato which is shown in Appendix I.

3.2. Climate of the experimental area

The area is characterized by hot and humid climate. The average rainfall of the locality of the experimental area is 209.06 mm, the minimum and maximum temperature is 11.10°C and 34.80ºC respectively. The average relative humidity was 75.8% during October, 2015 to February 2016.

3.3. Soil of the experimental field

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

3.4. Plant materials used

In this research work, the seeds of five tomato varieties were used as planting materials. The tomato varieties used in the experiments were Soysan, Unnayan, Minto hybrid tomato, Ratan, Holand. All varieties are collected from Siddique Bazar, Dhaka.

3.5. Raising of seedlings

Tomato seedlings were raised in two seedbeds of 3 m x 1m size. A distance of 50 cm was maintained between the beds. The soil was well prepared and converted into loose friable and dried mass by spading. All weeds and stubbles were removed and 10 kg well rotten cow-dung was mixed with the soil. Four gram of seeds was shown on each seedbed, according to the date. The seeds were sown in the seedbeds date1 November, 2015.Sevin85SP was applied around each seedbed as precautionary measure against ants, worm and other harmful insects. The emergence of the seedlings took place with 6 to 8 days after sowing. Shading by polythene with bamboo structure was provided over the seedbed to protect the young seedlings from the scorching sunshine or rain. After 10 days emergence, the seedlings were transferred into a second bed to obtain healthy and vigorous seedlings. Diathane M-45 was sprayed in the seedbeds @ 2 g/l, to protect the seedlings from damping off and other diseases. Weeding, Mulching and Irrigation were done as and when required.

3.6 Treatments and layout of the experiment

The experiment consisted of two factors; (A) Five varieties of tomato and (B) Two spacing. The levels of the two factors were as follows:

Factor A: Variety of tomato	**Factor B**: Spacing
V_1=Soysan	S_1=50 cm ×40 cm
V_2=Unnayan	S_2= 60 cm ×40 cm
V_2=Minto hybrid	
V_2=Ratan	
V_2=Holand	

3.6.1 Treatment combinations

There were 12 treatment combinations of different varieties and different plant spacing used in the experiment under as following:

1. V_1S_1	6. V_3S_2
2. V_1S_2	7. V_4S_1
3. V_2S_1	8. V_4S_2
4. V_2S_2	9. V_5S_1
5. V_3S_1	10. V_5S_2

3.7 Design and layout of the experiment

The experiment was laid out in Randomized complete Block Design (RCBD) having two factors and replicated three times. An area was divided into three equal blocks. Each block was consists of 10 plots where 10 treatment combinations were allotted randomly. These there were 30 unit plots altogether in the experiment. The size of each plot was 2m ×3m. The distance between two blocks and two plots were kept 1m and 0.80 m respectively. The layout of the experiment is presented in Appendix III.

3.8 Cultivation procedure

3.8.1 Land preparation

The land for growing the crop was first opened with a tractor. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and then the land was ready. Finally, the unit plots were prepared as 15 cm raised beds. The field layout and design or the experiment was followed immediately after land preparation.

3.8.2 Manure and fertilizers and its methods of application

Manure and fertilizers were applied in the experimental field as per the following doses.

Manure/ fertilizer	Total amount per hectare	Applied during land preparation	Applied in pit a week before transplanting	Applied as top dressing in rows	
				1st installment after 3 weeks of transplanting	2nd installment after 5 weeks of transplanting
Cow-dung	15t	10t/ha	5t/ha	-	-
Urea	300kg	-	100kg/ha	100 kg/ha	100 kg/ha
TSP	200kg	-	200kg/ha	-	-
MP	220kg	-	100kg/ha	60 kg/ha	60 kg/ha
Boric acid	12 kg/ha	-	12 kg/ha	-	-
$ZnSO_4$	10 kg/ha		10 kg/ha	-	-
$MgSO_4$	6 kg/ha		6 kg/ha	-	-

3.8.3 Transplanting of seedlings

Healthy and uniform 30 days old seedlings were uprooted separately from the seed bed and were transplanted in the experimental plots in the afternoon of 2 December, 2015. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage to the roots. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.8.4 Intercultural operations

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

a) Gap filling

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

b) Weeding and Mulching

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

c) Staking and Pruning

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

d) Irrigation

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

e) Plant protection

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

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

3.9 Harvesting

Fruits were harvested at 5-days intervals during early ripe stage when they attained slightly red color. Harvesting was started from 20 January, 2016 and was continued up to 15 April, 2016.

3.10 Data collection

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

3.10.1 Plant height

Plant height at final harvest was measured from sample plants in centimeter from the ground level to the tip of the longest stem and mean value was calculated. Plant height was also recorded at 15 days interval starting from 15 days of planting up to 75 days to observe the growth rate of plants. Lastly, the height was recorded at final harvest.

3.10.2 Number of leaves per plant

It was recorded by the following formula:

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

3.10.3 Number of primary branches per plant

It was measured by the following formula:

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

3.10.4 Number of secondary branches per plant

It was measured by the following formula:

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

3.10.5 Number of flowers per cluster

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

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

3.10.6 Number of fruits per cluster

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

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

3.10.7 Number of fruits per plant

It was recorded by the following formula

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

3.10.8 Fruit length

The length of fruit was measured with a slide calipers from the neck of the fruit to the bottom of 10 randomly selected fruits from each plot and their average was taken in centimeter (cm) as the length fruit.

3.10.9 Fruit breadth

Breadth of fruit was measured at the middle portion of 10 randomly selected fruits from each plot with a slide calipers and their average was taken in centimeter (cm) as the breadth of fruit.

3.10.10 Weight of individual fruit

Among the total number of fruits harvests during the period from first to final harvest, the fruits, except the first and last harvests, were considered for determining the individual fruit weight in gram (g).

3.10.11 Yield of fruits per plot

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

3.10.12 Yield of fruits per hectare

It was measured by the following formula

Fruit yield per hectare (t/ha) $= \frac{\text{Fruit yield per plot (kg) x 10000}}{\text{Area of plot in square meter x 1000}}$

3.10.13 Statistical analysis

The recorded data on various parameters were statistically analyzed by using MSTAT statistical package programme. The mean for all the treatments was calculated and analysis of variance for all the characters was performed by F-test. Difference between treatment means were determined by LSD Test at 5% level of probability according to Gomez and Gomez (1984).

CHAPTER IV

RESULTS AND DISCUSSION

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

4.1 Plant height

Plant height is the vertical special distribution of plat and is the function of cell division and cell elongation. Plant height is one of the important parameter, which is positively correlated with the yield of tomato (Taleb, 1994). Plant height was recorded at 15, 30, 45, 60 and 75 days after transplanting (DAT). Plant height at 15, 30, 45, 60 and 75 DAT due to the influence of different varieties was significant. The variety Minto hybrid (V_3) had the highest plant height (36.95, 59.05, 80.08, 83.35 and 96.27cm height at 15, 30, 45, 60 and 75 DAT, respectively). However, the lowest plant height (22.01, 49.31, 76.33 82.85 and 87.65 cm at 15, 30, 45, 60 and 75 DAT, respectively) was obtained from the variety Soysan (V_1) (Fig. 1 and appendix III). Varietal influence on plant height was also reported by Hossain *et al.* (1986).

The plant height was varied due to the different spacing at different days after transplanting. The tallest plant (27.41, 55.37, 77.83, 83.82 and 93.77 cm at 15, 30, 45, 60 and 75 DAT, respectively) was obtained from S_1 (50 cm × 40 cm spacing) and the shortest plant (27.01, 53.69, 76.84, 82.19 and 92.30 cm at 15, 30, 45, 60 and 75 DAT, respectively) was obtained in S_2 (60 cm × 40 cm spacing) (Fig. 2 and appendix III). The increased plant height at closer spacing was due to more competition for air and light.

The interaction effect of varieties and different spacing indicated a significant variation in plant height at 15, 30, 45, 60 and 75 DAT (Table 1 and appendix III). The tallest plant height (38.44, 62.77, 80.17, 84.93 and 97.57 cm at 15, 30, 45, 60 and 75 DAT, respectively) was found in V_3S_1 (Minto hybrid with 50 cm × 40 cm spacing), and the smallest plant height (21.59 cm, 49.07, 74.30, 81.03 and 82.23 at 15, 30, 45, 60 and 75 DAT, respectively) was found in V_1S_2 (Soysan with 60 cm × 40 cm spacing). The variation among the treatment combination was due to genetic potential of varieties with spacing.

4.2 Number of leaves per plant

A good number of leaves indicated better growth and development of crop. It is also possibly related to the yield of tomato. Variation in number of leaves per plant due to the influence of different varieties was significant at 15, 30, 45, 60 and 75 DAT. The variety 'Minto hybrid' (V_3) Tomato had the highest number of leaves per plant (10.21, 14.30, 23.80, 36.27 and 51.93significant at 15, 30, 45, 60 and 75 DAT, respectively). However, the lowest number of leaves per plant (7.47, 12.67, 21.17, 28.93 and 40.90 at 15, 30, 45, 60 and 75 DAT, respectively) was obtained from the variety Soysan (V_1) (Fig. 3 and appendix IV).

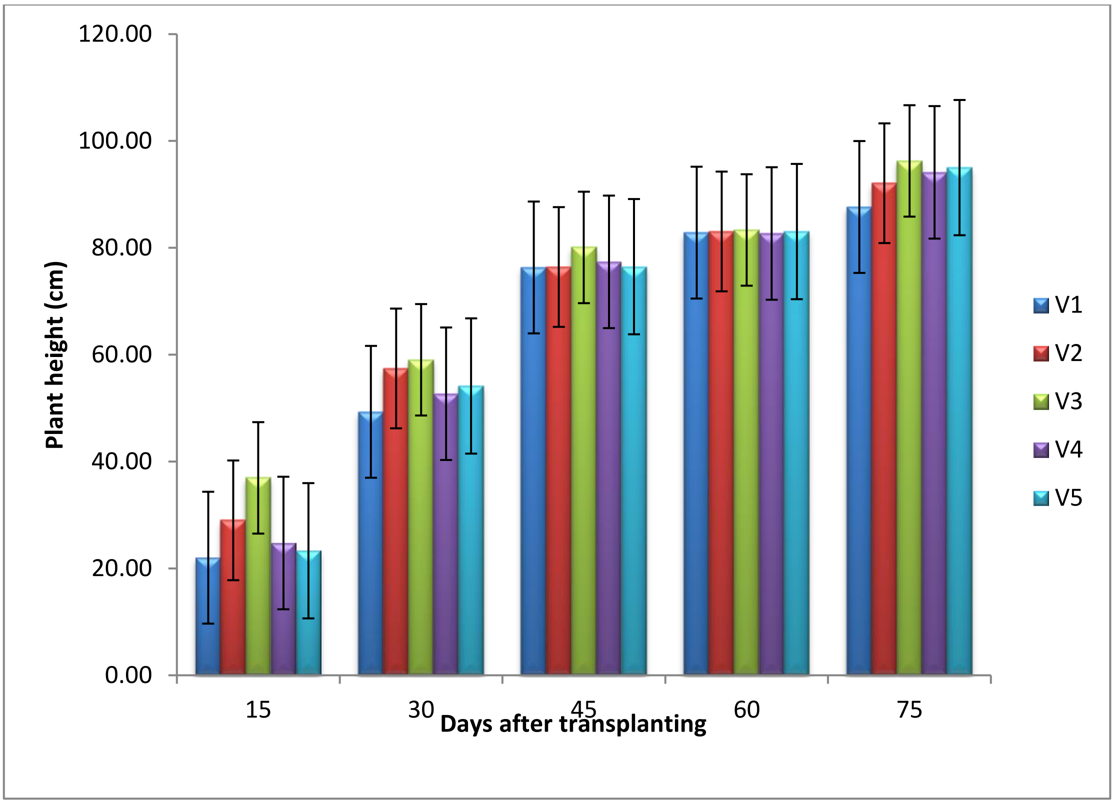

Fig. 1. Effect of variety on the plant height of tomato (V_1=Soysan, V_2=Unnayan, V_3=Minto hybrid, V_4=Ratan, V_5=Holand).

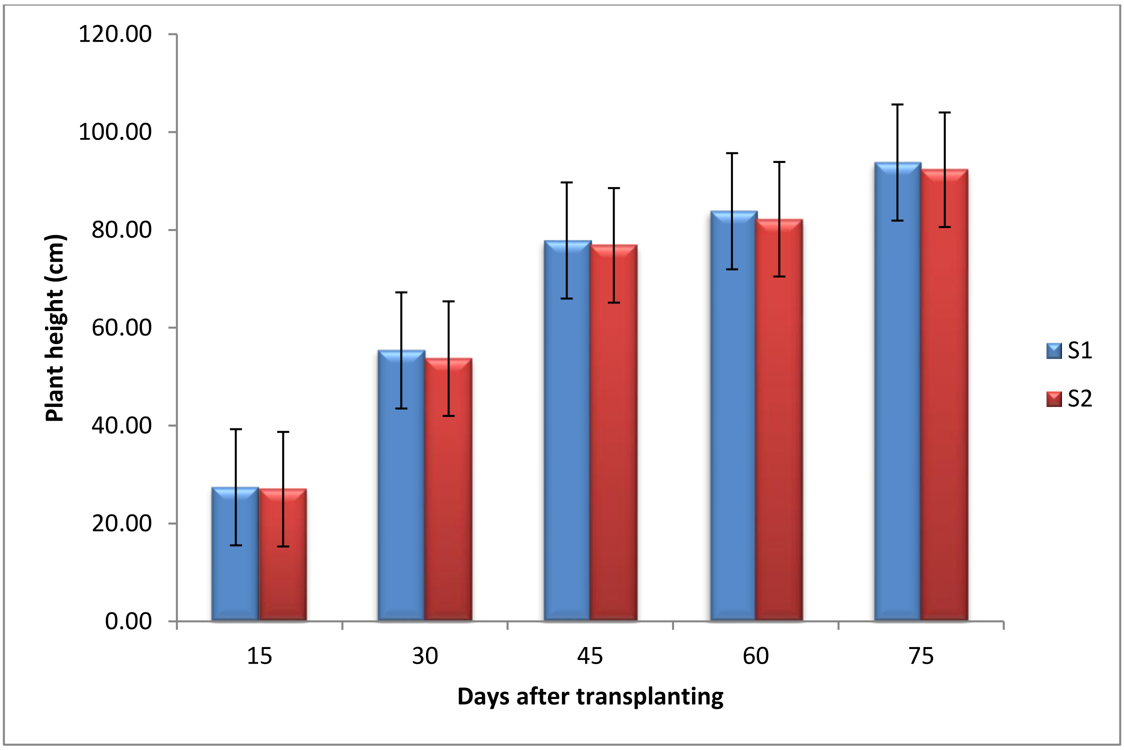

Fig. 2. Effect of spacing on the plant height of tomato (S_1=50 cm ×40 cm, S_2=60 cm ×40 cm)

Table 1. Interaction effect of variety and spacing on plant height of tomato

Treatment	Plant height (cm)				
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
V_1S_1	21.59 d	49.07 b	74.30 c	81.03 d	82.23 c
V_1S_2	22.44 cd	49.54 b	76.67 bc	84.67 ab	88.10 bc
V_2S_1	27.52 bc	57.76 ab	75.80 b	83.98 ab	94.97 ab
V_2S_2	30.47 b	57.11 ab	77.03 bc	82.15 bcd	93.07 ab
V_3S_1	38.44 a	62.77 a	80.17 a	84.93 a	97.57 a
V_3S_2	22.94 cd	55.03 ab	80.00 a	81.16 cd	96.09 a
V_4S_1	24.56 cd	52.20 b	78.11 bc	82.57 abcd	96.59 a
V_4S_2	24.97 cd	53.21 ab	78.36 bc	82.82 abcd	91.67 ab
V_5S_1	38.44 a	62.77 a	75.82 bc	82.93 abcd	96.37 a
V_5S_2	35.47 a	55.33 ab	77.13 bc	83.77 abc	93.67 ab
LSD $_{(0.05)}$	4.73	8.80	1.96	2.34	6.94
CV (%)	10.13	9.41	6.74	6.76	4.35

In column means with uncommon letter (s) are significantly different at 5% level of probability by LSD. (V_1=Soysan, V_2=Unnayan, V_3=Minto hybrid, V_4=Ratan, V_5=Holand, S_1=50 cm ×40 cm, S_2=60 cm ×40 cm)

The number of leaves per plant counted at different days after transplanting was influenced by spacing. Treatment S_2 (60 cm × 40 cm) produced maximum number of leaves per plant (8.95, 13.65, 21.84, 33.11 and 47.84 at 15, 30, 45, 60 and 75 DAT, respectively) and the minimum number of leaves per plant (8.11, 13.57, 21.52, 31.81 and 46.77 at 15, 30, 45, 60 and 75 DAT, respectively) number of leaves were recorded in S_1 (50 cm × 40 cm) treatment (Fig. 4 and appendix IV). As the spacing was increased number of leaves was found to be increased. This might have been due to the absorption of more nutrients, getting more sunlight on larger leaf area and better aeration influenced by the gradual increase in the spacing. This result agrees well with the findings of Kumer *et al.* (1998) and Rashid (1998). They found increased number of leaves per plant at wider spacing.

The interaction between variety and spacing was found significant on the number of leaves per plant (Table 2 and appendix IV). The maximum number of leaves per plant (12.43, 14.67, 23.93, 36.40 and 53.53 at 15, 30, 45, 60 and 75 DAT, respectively) was found in V_3S_2 treatment, whereas the lowest number of leaves per plant (7.00, 12.07, 19.73, 27.73 and 40.00 at 15, 30, 45, 60 and 75 DAT, respectively) was found in V_1S_1.

4.3 Number of primary branches per plant

Variety had no significantly effect on number of primary branch per plant (Table 3and appendix V). However, the variety 'Minto hybrid' had the highest number of primary branches per plant (6.47) and the lowest number of primary branches per plant (5.33) was obtained from the variety Soysan.

The number of primary branch per plant was not significantly influenced by spacing (Table 3 appendix V). Treatment S_2 (60 cm × 40 cm) produced maximum Number of primary branch per plant (5.88) and the minimum number of primary branch per plant (5.63) was recorded in S_1 (50 cm ×40 cm) treatment. As the spacing was increased number of primary branch per plant was found to be increased.

The interaction between different variety and spacing put significant effect on the number of primary branches per plant (Table 3 appendix V). The maximum number of primary branches per plant (6.60) was found in V_3S_2 treatment, which was identical with most of the treatments except $V_1S_1$and V_3S_1 treatments. The lowest number of primary branches per plant (4.13) was recorded in V_1S_1 treatment.

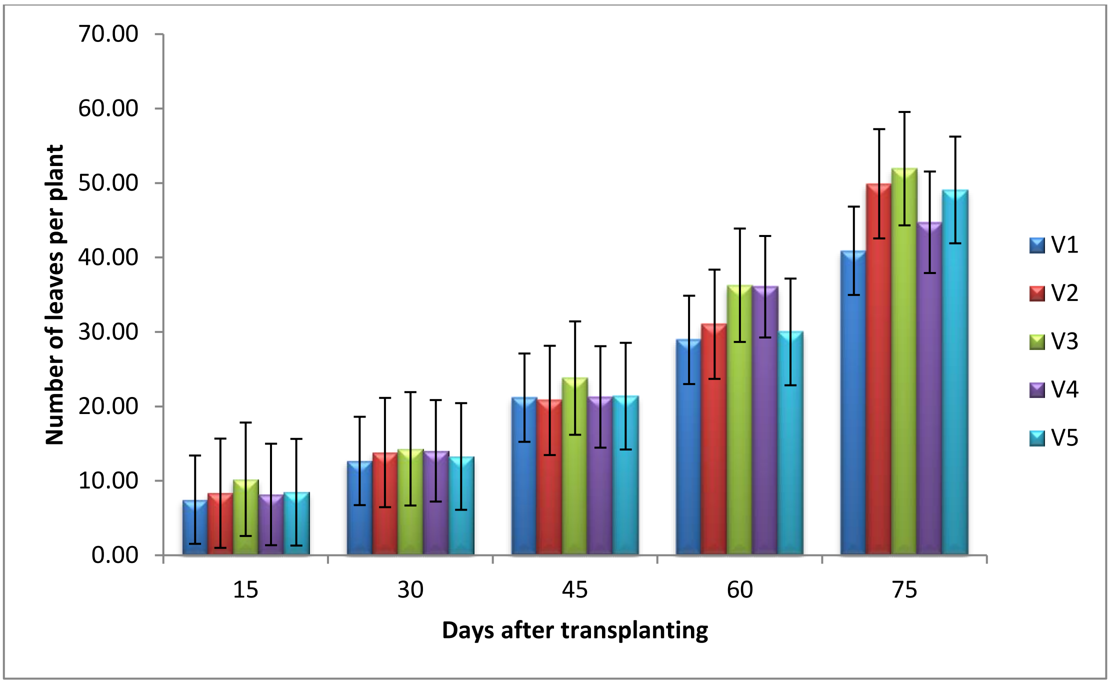

Fig. 3. Effect of variety on the number of leaves of tomato (V_1=Soysan, V_2=Unnayan, V_3=Minto hybrid, V_4=Ratan, V_5=Holand)

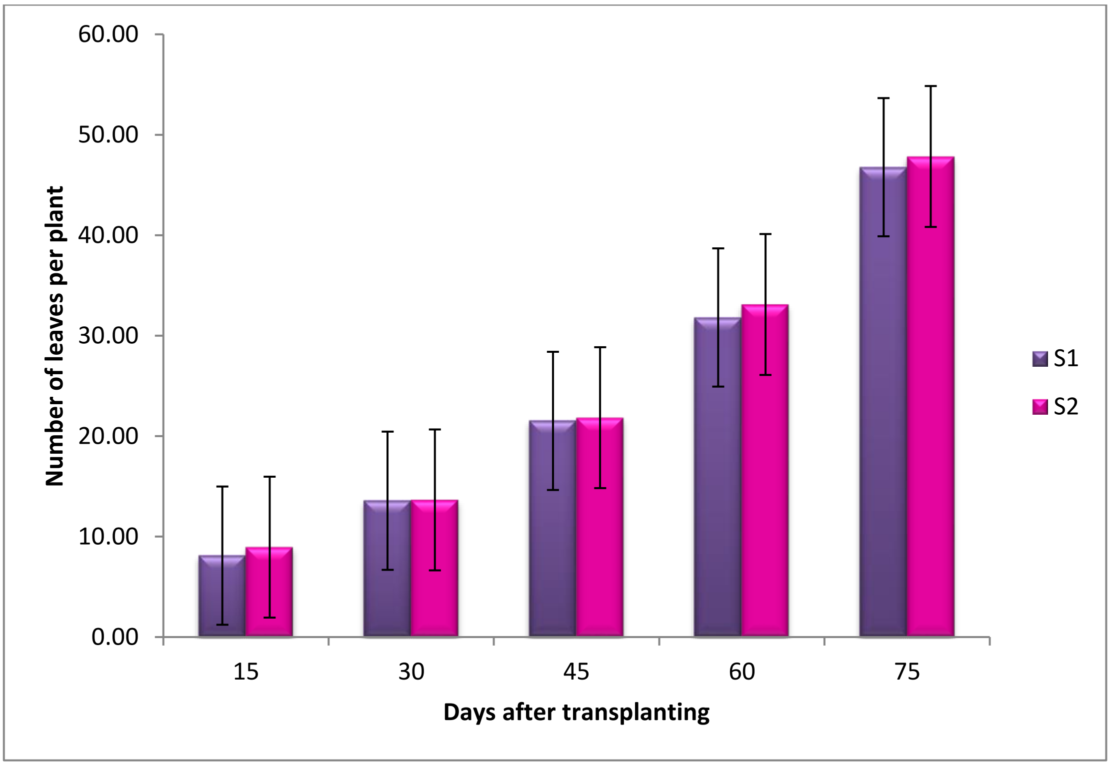

Fig. 4. Effect of planting time on the number of leaves of tomato (S_1=50 cm ×40 cm, S_2=60 cm ×40 cm)

Table 2. Interaction effect of variety and spacing on number of leave per plant of tomato

Treatment	Number of leaves per plant				
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
V_1S_1	7.00 b	12.07 e	19.73 f	27.73 c	40.00 f
V_1S_2	7.93 ab	12.53 de	20.80 def	29.00 bc	52.20 ab
V_2S_1	8.27 ab	14.27 ab	21.53 cdef	35.80 a	47.60 bcd
V_2S_2	8.40 ab	14.33 ab	23.67 ab	33.07 ab	41.80 ef
V_3S_1	9.13 ab	12.93 cde	21.87 bcde	36.33 a	46.60 cde
V_3S_2	12.43 a	14.67 a	23.93 a	36.40 a	53.53 a
V_4S_1	8.13 ab	14.33 ab	22.40 abcd	30.13 bc	50.33 abc
V_4S_2	8.20 ab	13.73 abc	20.13 ef	36.13 a	42.87 def
V_5S_1	8.00 ab	13.27 bcd	20.00 ef	30.13 bc	49.33 abc
V_5S_2	7.80 ab	14.00 abc	22.73 abc	29.87 bc	48.80 abc
LSD $_{(0.05)}$	4.47	1.07	1.72	3.98	4.98
CV (%)	10.56	13.53	5.49	9.06	6.13

In column means with uncommon letter (s) are significantly different at 5% level of probability by LSD. (V_1=Soysan, V_2=Unnayan, V_3=Minto hybrid, V_4=Ratan, V_5=Holand, S_1=50 cm ×40 cm, S_2=60 cm ×40 cm)

The interaction between different variety and spacing put significant effect on the number of primary branches per plant (Table 3 appendix V). The maximum number of primary branches per plant (6.60) was found in V_3S_2 treatment, which was identical with most of the treatments except $V_1S_1$and V_3S_1 treatments. The lowest number of primary branches per plant (4.13) was recorded in V_1S_1 treatment.

Table 3. Effect of variety and spacing interaction on number of primary and secondary branches per plant of tomato

Treatment	Number of primary branches per plant	Number of Secondary branches per plant
Variety		
V_1	5.33	3.37
V_2	5.53	3.70
V_3	6.47	3.83
V_4	5.93	3.67
V_5	5.70	3.70
LSD (0.05)	ns	ns
Spacing		
S_1	5.63	3.45
S_2	5.88	3.85
LSD (0.05)	ns	ns
Interaction: Variety and Spacing		
V_1S_1	4.13 c	3.00 b
V_1S_2	5.80 ab	3.73 ab
V_2S_1	6.53 a	3.73 ab
V_2S_2	6.33 ab	3.67 ab
V_3S_1	4.87 bc	3.93 a
V_3S_2	6.60 a	4.00 a
V_4S_1	5.67 ab	3.73 ab
V_4S_2	6.20 ab	3.33 ab
V_5S_1	5.73 ab	3.87 ab
V_5S_2	5.67 ab	3.53 ab
LSD (0.05)	1.37	0.80
CV (%)	9.90	12.73

In column means with uncommon letter (s) are significantly different at 5% level of probability by LSD. (V_1=Soysan, V_2=Unnayan, V_3=Minto hybrid, V_4=Ratan, V_5=Holand, S_1=50 cm ×40 cm, S_2=60 cm ×40 cm

4.4 Number of secondary branches per plant

Number of secondary branches per plant was not significantly influenced by variety (Table 3 appendix V). However, the variety ‘Minto hybrid’(V_3) had the highest number of secondary branches per plant (3.83) and the lowest number of secondary branches per plant (3.37) was obtained from the Soysan (V_1)treatment.

The different spacing had no significant influence influenced on the number of secondary branches per plant (Table 3 appendix V). The maximum number of secondary branches per plant (3.83) was produced by spacing S_2 (60 cm × 40 cm) treatment. The treatment S_1 (50 cm × 40 cm) produced the minimum number of secondary branches per plant (3.45).

The interaction between different variety and spacing put significant effect on the number of secondary branches per plant (Table 3 appendix V). The maximum number of secondary branches per plant (4.00) was found in V_3S_2 treatment, which was statistically similar with most of the treatment except V_1S_1.The lowest number of secondary branches per plant (3.00) was found in V_1S_1 treatment.

4.5 Number of flowers cluster per plant

There was a significant difference among the varieties in respect of number of flower cluster per plant (Table 4 appendix VI). The maximum number of flower cluster (7.17) was produced in 'Minto hybrid' (V_3) Tomato. The minimum number of flower cluster per plant (5.47) was produced in variety Soysan (V_1).

The different spacing had no significant effect on the number of flower cluster per plant (Table 4 appendix VI). The maximum number of flower cluster per plant (6.53) was produced from S_2 (60 cm × 40 cm) treatment and treatment S_1 (50 cm × 40 cm) produced the minimum number of flowers per cluster (5.56). Interaction of variety and spacing had significant influence on number of flowers cluster per plant (Table 4 and appendix VI). The maximum number of flowers cluster per (7.53) was found in 'Minto hybrid' with spacing 60 cm ×40 cm. whereas the minimum number of flower clusters per plant (4.80) was found in 'Soysan' with spacing 50 cm × 40 cm.

Table 4. Effect of variety and spacing interaction on number of flower clusters per plant, number of fruits per cluster and number of fruits per plant of tomato

Treatment	Number of flowers cluster per plant	Number of fruits per cluster	Number of fruit per plant
Variety			
V_1	5.47 d	3.60 b	12.12 c
V_2	5.73 c	3.93 b	15.05 b
V_3	7.17 a	5.43 a	16.72 a
V_4	5.77 c	4.50 b	12.89 c
V_5	6.10 b	4.07 b	12.56 c
LSD $_{(0.05)}$	0.25	0.89	3.49
Spacing			
S_1	5.56	4.01	13.21
S_2	6.53	4.60	14.46
LSD (0.05)	ns	ns	ns
Interaction: Variety and Spacing			
V_1S_1	4.80 b	3.20 c	10.53 d
V_1S_2	6.47 ab	3.80 bc	16.11 a
V_2S_1	5.20 ab	3.87 bc	12.37 bc
V_2S_2	6.80 ab	4.00 bc	14.00 b
V_3S_1	6.27 ab	4.93 ab	16.40 a
V_3S_2	7.53 a	5.93 a	16.72 a
V_4S_1	5.80 ab	4.00 bc	13.71 bc
V_4S_2	5.73 ab	5.20 ab	13.41 bc
V_5S_1	5.73 ab	4.07 bc	13.04 bc
V_5S_2	6.13 ab	4.07 bc	12.08 cd
LSD (0.05)	2.10	1.28	1.70
CV (%)	12.73	5.66	7.29

In column means with uncommon letter (s) are significantly different at 5% level of probability by LSD. (V_1=Soysan, V_2=Unnayan, V_3=Minto hybrid, V_4=Ratan, V_5=Holand, S_1=50 cm ×40 cm, S_2=60 cm ×40 cm

4.6 Number of fruits per cluster

Number of fruits per cluster due to the influence of different varieties was significant (Table 4 and appendix VI). The variety 'Minto hybrid' had the highest number of fruits per cluster (5.43). However, the lowest number of fruits per cluster (3.60) was obtained from the variety 'Soysan', which were statistically similar 'Unnayan', 'Ratan' and 'Holand'. This result partially agreed with the findings of Hossain (2001).

The different spacing showed insignificant variation in the number of fruits per cluster (Table 4 and appendix VI). The maximum number of fruits per cluster (4.60) was produced by S_2 (60 cm ×40 cm) treatment and S_1 (50 cm ×40 cm) produced the minimum number of fruits per cluster (4.01).

The variation among the treatment combinations of variety and spacing was found significant (Table 4 and appendix VI). The maximum number of fruits per cluster (5.93) was found in V_3S_2 treatment, which was identical with V_3S_1 and V_4S_2 treatments. The minimum number of fruits per cluster (3.20) was found in V_1S_1 treatment.

4.7 Number of fruits per plant

There was a significant difference among the varieties in the number of fruit per plant (Table4 and appendix VI). The maximum number of fruits per plant (16.72) was produced by 'Minto hybrid' (V_3). The minimum number of fruit per plant (12.12) was produced in Soysan (V_1). This variation among the varieties was due to the genetically potentiality of the varieties and is supported by Hossain *et al.* (1986).

The different spacing showed insignificant variation in the number of fruits per plant (Table 4 and appendix VI). The maximum number of fruit per plant (14.46) was produced from S_2 (60 cm × 40 cm) treatment and treatment S_1 (50 cm × 40 cm) produced the minimum number of fruits per plant (13.21).

A significant variation was observed among the treatment combinations in number of fruits per plant (Table 4 and appendix VI). The maximum number of fruits per plant (41.80) was found in V_3S_2, which was statistically similar with V_3S_1 and V_2S_1treatment, whereas the minimum number of fruits per plant (26.33) was found in V_1S_1.

4.8 Length of fruit

A significant variation in the length of fruit was found among the varieties (Table 5 and appendix VII). The longest fruit length (7.78 cm) was obtained from 'Minto hybrid' (V_3) closely followed by Ratan (V_4) and Holand (V_5) and the shortest fruit length (6.84 cm) was obtained from 'Soysan' (V_1). Hossain (2001) and Sing and Sahu (1998) also reported varietal influence on the length of fruit.

The different spacing had no significant effect on the length of fruit. However, the longest fruit (52.81 cm) was produced by S_2 (60 cm × 40 cm) and S_1 (50 cm × 40 cm) produced the shortest fruit length (51.27 cm) (Table 5 and appendix VII).

The variation in fruit length due to interaction effect of variety and spacing was found statistically significant (Table 5 and appendix VII). The maximum fruit length (7.81 cm) was found in V_3S_2, whereas the minimum fruit length (6.71 cm) was found from V_1S_1.

Table 5. Effect of variety and spacing on fruit length and fruit breadth of tomato

Treatment	Fruit length (cm)	Fruit breadth (cm)
Variety		
V_1	6.84 b	14.14 a
V_2	6.99 b	14.87 ab
V_3	7.78 a	15.43 a
V_4	7.05 ab	14.48 ab
V_5	7.30 ab	14.41 ab
LSD $_{(0.05)}$	0.76	1.11
Spacing		
S_1	7.04	14.54
S_2	7.35	14.79
LSD (0.05)	ns	ns
Interaction Variety × Spacing		
V_1S_1	6.71 d	13.88 a
V_1S_2	7.18 a-d	14.32 ab
V_2S_1	7.75 a	14.67 ab
V_2S_2	6.73 cd	15.07 ab
V_3S_1	6.95 bcd	14.71 ab
V_3S_2	7.81 a	15.53 a
V_4S_1	7.37 abc	14.41 ab
V_4S_2	6.74 cd	14.65 ab
V_5S_1	7.26 abcd	14.11 ab
V_5S_2	7.41 ab	15.33 ab
LSD $_{(0.05)}$	0.58	1.41
CV (%)	4.56	5.60

In column means with uncommon letter (s) are significantly different at 5% level of probability by LSD. (V_1=Soysan, V_2=Unnayan, V_3=Minto hybrid, V_4=Ratan, V_5=Holand, S_1=50 cm ×40 cm, S_2=60 cm ×40 cm

4.9 Fruit breadth

A significant variation in the fruit breadth was found among the varieties (Table 5 appendix VII). The maximum fruit diameter (15.73 cm) was obtained from 'Minto hybrid' (V_3) and the minimum fruit diameter (14.14 cm) was obtained from Soysan (V_1). Hossain (2001) and Singh and Sahu (1998) also reported varietal influence on the fruit breadth.

There was a non significant difference among the spacing in the fruit breadth (Table 5 and appendix VII). The largest fruit diameter (14.79 cm) was produced by S_2 (60 cm × 40 cm) spacing and S_1 (50 cm × 40 cm) spacing produced the shortest fruit diameter (14.54 cm).

The variation in fruit diameter due to the combined effect of variety and spacing was found statistically significant (Table 5 and appendix VII). The largest fruit diameter (15.53 cm) was found in V_3S_2 which was identical with all the treatments. The shortest fruit diameter (13.88 cm) was found in V_1S_1.

4.10 Individual fruit weight

The weight of individual fruit weight was significantly influenced by different varieties (Table 6 and appendix VIII). The largest individual fruit weight (65.52 g) was obtained from 'Minto hybrid' (V_3) closely followed by Unnayan (V_2) and Rattan (V_4). The shortest fruit weight (52.15 g) was obtained from Soysan. The wide variation among the varieties in respect of individual fruit weight was due to the varietal characteristics. Varietal influence on individual fruit weight was also reported by Hossain *et al.* (1986) and Meher *et al.* (1994).

Spacing did not influence on the weight of individual fruit weight (Table 6and appendix VIII). The maximum individual fruit weight (60.19 g) was produced by S_2 (60 cm × 40 cm) treatment and S_1 (50 cm × 40 cm) produced the lowest individual fruit weight (59.51 g).

Individual fruit weight was significantly affected by combined effect of varieties and spacing. The highest individual fruit weight (68.47 g) was found in V_3S_2

treatment, which was identical with (V_2S_2) treatment (66.83g), whereas the lowest fruit length (44.10 g) was found in V_1S_1 treatment (Table 6 and appendix VIII).

Table 6. Effect of variety and spacing interaction on the yield contributing characters and yield of tomato

Treatment	Individual fruit eight (g)	Yield per plot (kg)	Yield (t/ha)
Variety			
V_1	52.15 b	17.56 c	14.56 c
V_2	61.80 a	18.86 bc	15.72 bc
V_3	65.52 a	20.59 a	34.30 a
V_4	64.60 a	10.61 b	17.67 a
V_5	55.17 b	8.74 c	14.63 c
LSD $_{(0.05)}$	4.22	4.79	6.27
Spacing			
S_1	59.51	22.56	37.60
S_2	60.19	23.95	39.92
LSD $_{(0.05)}$	ns	ns	ns
Interaction: Variety x Spacing			
V_1S_1	44.10 a	13.79 a	22.98 c
V_1S_2	61.03 cd	21.34 bc	35.56 bc
V_2S_1	62.57 bc	19.47 bc	32.44 bc
V_2S_2	66.63 ab	18.26 bc	30.44 bc
V_3S_1	60.20 cd	40.18 b	66.96 a
V_3S_2	68.47 a	42.16 a	70.26 a
V_4S_1	53.03 a	19.42 bc	32.36 bc
V_4S_2	57.30 de	23.00 b	38.34 b
V_5S_1	62.57 bc	19.95 bc	33.24 bc
V_5S_2	62.57 bc	15.00 bc	25 bc
LSD (0.05)	4.60	7.61	12.68
CV (%)	5.60	9.08	8.78

In column means with uncommon letter (s) are significantly different at 5% level of probability by LSD. (V_1=Soysan, V_2=Unnayan, V_3=Minto hybrid, V_4=Ratan, V_5=Holand, S_1=50 cm ×40 cm, S_2=60 cm ×40 cm

4.11 Yield of fruits per plot

The different varieties of tomato significantly influenced on the yield of fruits per plot ($6m^2$) (Table 6 and appendix VIII). The maximum yield of fruits per plot was obtained from Minto hybrid (20.59 kg) followed by Ratan (18.86 kg/plot) and the minimum yield of fruits per plot was obtained from Soysan (8.74 kg).

The different spacing had no significant effect on the yield of fruits per plot (Table 6 and appendix VIII). The maximum yield of fruits per plot (23.95 kg) was produced by S_2 (60 cm × 40 cm) treatment and S_1 (50 cm × 40 cm) treatment produced the minimum yield of fruits per plant (22.56kg).

The combination effect of variety and spacing put significant on yield of fruit per plot (Table 6 and appendix VIII). The highest yield of fruits per plot (42.16 kg) was obtained from 'Minto hybrid' with spacing 60 cm ×40 cm (V_3S_2), which was statistically similar with V_3S_1.The lowest yield of fruits per plot (13.76 kg) was obtained from Soysan with spacing of 50 cm ×40 cm (V_1S_1).

4.12 Fruit yield per hectare

Fruit yield per hectare was significantly influenced by different varieties of tomato (Table 6 and appendix VIII). The maximum yield of fruits per hectare (34.31 t) was obtained from 'Minto hybrid'(V_3) and the minimum yield of fruits per hectare (14.56 t) was obtained from Soysan (V_1). The variety 'Ratan' gave the reasonable fruit yield (31.44 t/ha). The yield variation might be due to the genetic potentiality of the tomato varieties. Ahmed *et al*. (1986); Berry *et al.* (1995); Singh and Sahu (1998) and Hamid *et al*. (2055) also reported varietal influence on fruit yield of tomato per hectare.

The different spacing had no significant effect on the yield of fruits per hectare (Table 6 and appendix VIII). However, the maximum yield of fruits per hectare was obtained from the width spacing 60 cm × 40 cm (39.92 tones) but the closer spacing 50 cm ×40 cm gave the minimum yield of fruits per hectare (37.60 t). The wider spacing (60 cm ×40 cm) gave higher yield than the closer spacing (50 cm ×40 cm). Sharma *et al.* (2001) obtained the maximum yield of tomato from 60 cm × 45 cm spacing when evaluated three spacing (60 cm × 30 cm, 60 cm × 45 cm and 60 cm × 60 cm)

The combined effect of variety and spacing on yield of fruits per hectare was significant (Table 6 and appendix VIII). The highest yield of fruits per hectare (70.26 t) was obtained from 'Minto hybrid' with wider spacing 60 cm × 40 cm (V_3S_2), which was statistically similar with V_3S_1 (66.96t). The lowest yield of fruits per hectare (22.98 t) was obtained from 'Soysan' with closer spacing 50 cm × 40 cm (V_1S_1).

CHAPTER V

SUMMARY AND CONCLUSION

The growth, yield contributing characters and yield of tomato largely depend on soil, climatic conditions, variety and agronomic practices. Among these, spacing and variety play a vital role.

The field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh from October 2015 to April 2016 to evaluate the effect of variety and spacing on growth and yield of tomato. Five varieties, *viz*. Soysan, Unnayan, 'Minto hybrid', Ratan, Holand and spacing *viz*., S_1 (50cm × 40 cm) and S_2 (60 cm × 40 cm) cm were used to conduct this experiment. The experiment was laid out in Randomized complete Block Design (RCBD) having two factors and replicated three times. Data were taken on the growth, yield contributing characters and yield, and the collected data were statistically analyzed for evaluation of the treatment effects. The summary of the results has been described in this chapter.

Plant height and number of leaves per plant at 15, 30, 45, 60 and 75 days after transplanting (DAT) due to the influence of different varieties was significant. The variety Minto hybrid (V_3) had the highest plant height (36.95, 59.05, 80.08, 83.35 and 96.27cm height at 15, 30, 45, 60 and 75 DAT, respectively). The variety 'Minto hybrid' had the highest number of leaves per plant (10.21, 14.30, 23.80, 36.27 and 51.93 significant at 15, 30, 45, 60 and 75 DAT).

Different varieties did not significantly influence on number of primary branch and secondary branch per plant. However, the variety 'Minto hybrid' had the highest number of primary branches per plant (6.47) and number of secondary branches per plant (3.83).

There was a significant difference among the varieties in the number of flower clusters per plant, number of fruits per cluster and number of fruits per plant. The maximum number of flower clusters (7.17), number of fruits per cluster (5.43) and number of fruits per plant (16.72) was produced in 'Minto hybrid'.

A significant variation in the length of fruit and fruit breadth was found among the varieties. The maximum fruit length (7.78 cm) and fruit diameter (15.73 cm) was obtained from 'Minto hybrid' tomato.

The weight of individual fruit was significantly influenced by different varieties. The heaviest fruit weight (65.52 g) was obtained from 'Minto hybrid'. The different varieties of tomato significantly influenced on the yield of fruits per plot ($6m^2$). The maximum yield of fruits per plot (20.59kg) was obtained from 'Minto hybrid' and the minimum yield of fruits per plot (8.74 kg) was obtained from Soysan. The maximum yield of fruits per hectare (34.31 t) was obtained from 'Minto hybrid' and the minimum yield of fruits per hectare (14.56 t) was obtained from Soysan.

All parameters were affected due to the different spacing. The tallest plant (27.41, 55.37, 77.83, 83.82 and 93.77 cm at 15, 30, 45, 60 and 75 DAT, respectively) was obtained from S_1 (50 cm × 40 cm spacing).

Treatment S_2 produced highest number of leaves (8.95, 13.65, 21.84, 33.11 and 47.84 at 15, 30, 45, 60 and 75 DAT, respectively). Treatment S_2 produced maximum number of primary branch per plant (5.88). The maximum number of secondary branches per plant (3.83) was produced by spacing on S_2 treatment.

The highest number of flower clusters per plant (6.53), number of fruits per cluster (4.60) and number of fruits per plant (16.72) was produced from S2 treatment. The longest fruit length (52.81 cm) was produced by S2. The maximum fruit diameter (14.79 cm) was produced by S_2 spacing. The maximum individual fruit weight (60.19 g) was produced by S_2 treatment. The maximum yield of fruits per plot (23.95 kg) was produced by S_2 treatment and S1 treatment produced the minimum yield of fruits per plant (22.56 kg). The maximum yield of fruits per hectare (39.92 tones) was obtained from spacing 60 cm × 40 cm and spacing 50 cm × 40 cm obtained the minimum yield of fruits per hectare (37.60 t).

The interaction between variety and spacing was found to be significant in all parameters. The maximum plant height (38.44, 62.77, 80.17, 84.93 and 97.57 cm at 15, 30, 45, 60 and 75 DAT, respectively) was found in V_3S_1 (Minto hybrid with 50 cm × 40 cm spacing). The maximum number of leaves per plant (12.43, 14.67, 23.93, 36.40 and 53.53 at 15, 30, 45, 60 and 75 DAT, respectively) was found in V3S2 treatment. The maximum number of primary branches per plant (6.60) and number of secondary branches per plant (4.00) was found in V_3S_2 treatment.

The maximum number of flower clusters per plant (7.53), number of fruits per cluster (5.93) and number of fruits per (16.72) plant was found in 'Minto hybrid' with spacing 60 cm× 40 cm. The variety 'Minto hybrid' produced the highest fruit length and breadth (7.78 cm and 15.53 cm) when planted on spacing 60 cm × 40 cm. The maximum individual fruit weight (68.47 g) was found in V3S2 treatment. The combined effect of variety and spacing was significant on yield of fruit per plot. The highest yield of fruits per plot (42.16 kg) was obtained from 'Minto hybrid' with spacing 60 cm × 40 cm. The highest yield of fruits per hectare (70.26

t) was obtained from 'Minto hybrid' with spacing 60 cm × 40 cm, which was statistically similar with V_3S_1. The lowest yield of fruits per hectare (22.98 t) was obtained from Soysan with spacing 50 cm × 40 cm.

Conclusion

Based on the above findings, the following conclusion might be drawn:

1. The growth parameters *viz*. plant height leaves plant^{-1}, primary and secondary branches plant^{-1} and yield attributes *viz*. flower clusters plant^{-1}, fruits cluster^{-1}, fruits plant^{-1}, fruit size (length × breadth) and individual fruit weight were found maximum from the variety of Minto hybrid.

2. The variety Minto hybrid produced the maximum fruit yield. The reasonable fruit yield was also obtained from the variety Ratan.

3. The wider spacing of 60 cm × 40 cm gave better yield compared to the closer spacing of 50 cm × 40 cm.

4. The variety Minto hybrid in combination with 60 cm × 40 cm spacing produced the maximum fruit yield, which was identical with the same variety with 50 cm × 40 cm spacing.

5. The variety Ratan coupled with 60 cm × 40 cm spacing gave the reasonable fruit yield of tomato.

Recommendation

i. The variety Minto hybrid and the spacing 60 cm × 40 cm are suitable for obtained maximum fruit yield of tomato.

ii. The findings obtained from the present investigation should be confirmed by conducting similar type of experiments in different Agro-Ecological Zones (AEZs) of Bangladesh.

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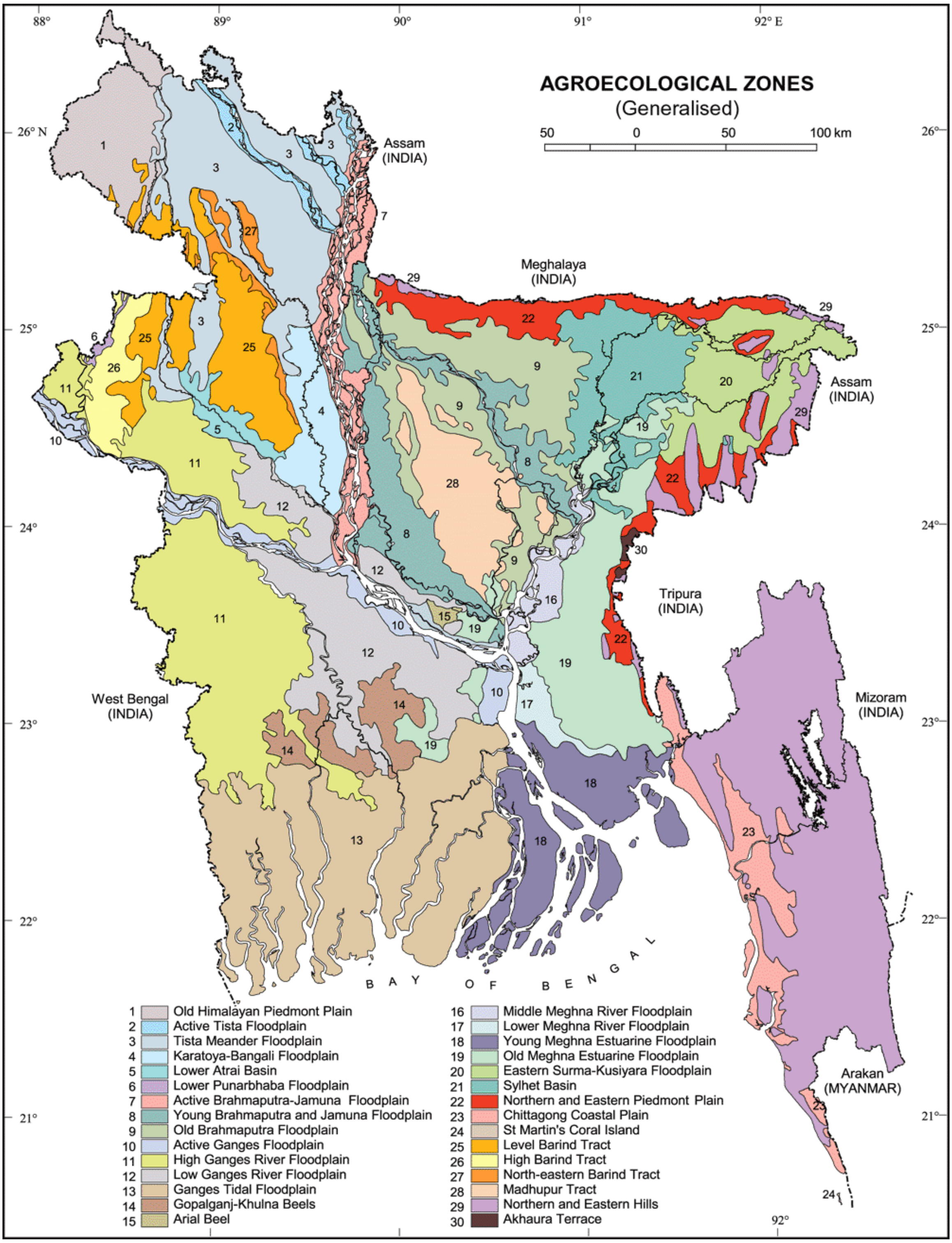
APPENDICES

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



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

A. Morphological characteristics of the experimental field

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

Source: Soil Resources Development Institute (SRDI)

B. Physical and Chemical properties of the Initial soil

Characteristics	**Value**
Practical size analysis	
Sand (%)	16
Silt (%)	56
Clay (%)	28
Silt + Clay (%)	84
Textural class	Silty clay loam
pH	5.56
Organic matter (%)	0.25
Total N (%)	0.02
Available P (μgm/gm soil)	53.64
Available K (me/100g soil)	0.13
Available S (μgm/gm soil)	9.40
Available B (μgm/gm soil)	0.13
Available Zn (μgm/gm soil)	0.94
Available Cu (μgm/gm soil)	1.93
Available Fe (μgm/gm soil)	240.9
Available Mn (μgm/gm soil)	50.6

Source: Soil Resources Development Institute (SRDI)

Appendix III: Analysis of variance of the data on plant height of tomato as influenced at dates of transplanting

Sources of Variation	Degrees of freedom	Means square				
		Plant height (cm)				
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
Replication	2	0.09	15.66	19.67	53.48	78.252
Factor A	4	219.49*	89.43*	15.22*	0.37*	68.192*
Factor B	1	1.18	20.97	7.41	19.94	16.339
AB	4	6.83*	17.25*	6.35*	6.86*	78.243*
Error	18	7.60	26.32	8.37	9.72	16.378

*significant at 5% level of probability

Appendix IV: Analysis of variance of the data on number of leaves per plant of tomato as influenced at dates of transplanting

Sources of Variation	Degrees of freedom	Means square				
		Number of leaves per plant				
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
Replication	2	5.85	10.01	25.31	15.48	56.185
Factor A	4	6.21*	2.55*	8.70*	72.04*	118.345*
Factor B	1	5.36	0.05	0.77	12.55	8.533
AB	4	7.01*	2.60*	6.47*	5.39*	16.19*
Error	18	6.79	3.39	11.27	8.65	8.412

*significant at 5% level of probability

Appendix V: Analysis of variance of the data on Number of primary branches per plant and number of secondary branches per plant of tomato

Sources of Variation	Degrees of freedom	Means square	
		Number of primary branches per plant	Number of secondary branches per plant
Replication	2	1.697	0.121
Factor A	4	1.345	0.179
Factor B	1	0.481	1.2
AB	4	2.501*	0.127*
Error	18	0.64	0.216

*significant at 5% level of probability

Appendix VI: Analysis of variance of the data on Number of flower clusters per plant, Number of fruits per cluster and Number of fruits per plant of tomato

Sources of Variation	Degrees of freedom	Means square		
		Number of flowers cluster per plant	Number of fruits per cluster	Number of fruit per plant
Replication	2	1.157	12.369	239.177
Factor A	4	3.005*	143.018*	39.155*
Factor B	1	2.821	99.372	17.88
AB	4	0.651*	13.855*	7.637*
Error	18	0.554	6.171	5.632

*significant at 5% level of probability

Appendix VII: Analysis of variance of the data on fruit length and fruit breadth of tomato

Sources of Variation	Degrees of freedom	Means square	
		Fruit length (cm)	Fruit breadth (cm)
Replication	2	0.587	0.521
Factor A	4	0.809*	1.504*
Factor B	1	0.743	0.461
AB	4	0.113*	0.238*
Error	18	0.324	0.675

*significant at 5% level of probability

Appendix VIII: Analysis of variance of the data on weight of fruits, yield per plot and yield per hectare of tomato

Sources of Variation	Degrees of freedom	Means square		
		Individual fruit weight (g)	Yield per plot (kg)	Yield (t ha^{-1})
Replication	2	106.57	6.026	16.748
Factor A	4	209.549*	38.745*	107.594*
Factor B	1	3.468	0.259	0.708
AB	4	123.3*	5.338*	14.823*
Error	18	73.198	10.524	29.224

*significant at 5% level of probability