YIELD AND MORPHO-PHYSIOLOGICAL PERFORMANCE OF HYBRID AND INBRED TOMATO VARIETIES IN WINTER AND SUMMER SEASONS

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MASTER OF SCIENCE (M.S.)
IN
AGRICULTURAL BOTANY

DEPARTMENT OF AGRICULTURAL BOTANY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

DECEMBER, 2013

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REGISTRATION NO. : 07-02269

A Thesis
Submitted to the Department of Agricultural Botany,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

IN

AGRICULTURAL BOTANY

SEMESTER: JULY-DECEMBER, 2013

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CERTIFICATE

This is to certify that the thesis entitled ***"YIELD AND MORPHO-PHYSIOLOGICAL PERFORMANCE OF HYBRID AND INBRED TOMATO VARIETIES IN WINTER AND SUMMER SEASONS"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (M.S.)*** *in* ***AGRICULTURAL BOTANY****, embodies the results of a piece of bona fide research work carried out by* ***MD. ELIAS HOSSAIN,*** *Registration no.* ***07-02269*** *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:
Place: Dhaka, Bangladesh

Prof. Dr. Kamal Uddin Ahamed
Supervisor

ACKNOWLEDGEMENTS

All the praises, gratitude and thanks are due to the omniscient, omnipresent and omnipotent Allah Who enabled me to pursue education in Agriculture discipline and to complete this thesis for the degree of Master of Science (M.S.) in Agricultural Botany.

I wish to express my sincere appreciation, profound gratitude and best regards to my supervisor, ***Prof. Dr. Kamal Uddin Ahamed****, Dept. of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, for his guidance and supervision in carrying out the research work, continuous inspiration, constructive comments and encouragement during my research work and guidance in preparation of manuscript of the thesis. I am grateful to my co-supervisor* ***Prof. Dr. Md. Moinul Haque,*** *Dept. of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka Bangladesh, for his valuable advice, constructive criticism and factual comments in upgrading the research with all possible help during the research period and preparation of the thesis.*

I would like to express my deepest respect and boundless gratitude to Prof. A.M.M Shamsuzzaman, Dept. of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka Bangladesh for cordial co-operation and inspirations throughout the course of this study and research work.

I would like to show my gratitude and honour to my teachers & colleagues of the department of Agricultural Botany, Prof. Asim Kumar Bhadra, Prof. Dr. Shahnaz Sarkar, Dr. Mohammad Mahbub Islam, Dr. Md. Ashabul Hoque, Nasima Akhter, Md. Tofael Hossain and Rezowana Nizam, who made my ideas clear and vision broad.

I am indebted and like to express my profound and grateful gratitude to my beloved parents, wife, classmates and friends for their blessings, encouragement and inspiration.

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Dated: December, 2013 ***The Author***

SAU, Dhaka

YIELD AND MORPHO-PHYSIOLOGICAL PERFORMANCE OF HYBRID AND INBRED TOMATO VARIETIES IN WINTER AND SUMMER SEASONS

ABSTRACT

Two consecutive pot culture experiments were conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka to study the morpho-physiologycal and yield performance of two hybrid (BARI Hybrid Tomato-4 and BARI Hybrid Tomato-5) and three inbred (BARI Tomato-2, BARI Tomato-14 and BARI Tomato-15) tomato varieties during the winter and summer seasons of 2013-2014. Both the experiments were carried out using Randomized Complete Block Design (RCBD) with four replications. The results revealed that the best vegetative growth was found during the summer season but reproductive parameters showed best results during the winter season. In the first experiment during winter season, the maximum plant height at different days after transplanting was observed in BARI Hybrid Tomato-5. BARI Hybrid Tomato-5 accumulated maximum root dry mass (1.82 g plant^{-1}) while accumulation of shoot dry mass (17.52 g plant^{-1}) and total vegetative dry mass (19.10 g plant^{-1}) was maximum in BARI Tomato-2. BARI Tomato-14 required minimum time (23.42 days) for first appearance of inflorescence. Maximum flower clusters per plant (9.58) and floral buds per cluster (7.00) were observed in BARI Toamto-14 and BARI Hybrid Tomato-5 respectively. BARI Tomato-2 produced maximum flowers (5.31) and fruits (4.81) per cluster whereas a maximum fruits per plant (41.33) was produced by BARI Hybrid Tomato-4. The average fruit weight (74.19 g fruit^{-1}) was maximum in BARI Tomato-14 and the highest total soluble solid (5.42 %) was found in the fruits of BARI Hybrid Tomato-5. The tomato yield per hectare was maximum (58.19 t ha^{-1}) in BARI Tomato-14, which was statistically similar with BARI Tomato-2, and BARI Hybrid Tomato-5. In the second experiment during summer season, the results showed that the plant height at different days after transplanting, root dry mass (2.06 g plant^{-1}), shoot dry mass (22.53 g plant^{-1}) as well as total vegetative dry mass (24.53 g plant^{-1}) were maximum in BARI Hybrid Tomato-5. BARI Tomato-14 required minimum time (22.66 days) for first appearance of inflorescence. BARI Hybrid Tomato-5 produced maximum flower clusters per plant (9.58) and floral buds per cluster (7.00) whereas the maximum flowers per cluster (4.71) was produced by BARI Hybrid Tomato-4. Inbred varieties completely failed to set fruit in summer season, on the other hand hybrid varieties were able to set fruit. However, a complete failure of fruit yield at final stage was observed due to premature fruit drop of BARI Hybrid Tomato-4 and BARI Hybrid Tomato-5.

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LIST OF ABBREVIATIONS

ABBREVIATIONS	FULL WORD
@	At the rate of
AEZ	Agro-Ecological Zone
ANOVA	Analysis of variance
BARI	Bangladesh Agriculture Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BW	Bacterial wilt
cm	Centimeter
CV	Co-efficient of variance
DAT	Days after transplanting
df	Degree of freedom
DTII	Days to 1^{st} inflorescence initiation
EC	*Emulsifiable concentrate*
ems	Error mean square
FAOSTAT	Food and Agricultural Organization Statistics
LS	Level of significance
LSD	Least significant difference
M	Meter
mm	Millimeter
^{o}C	Degree centigrade
PGR	Plant growth regulator
SAU	Sher-e-Bangla Agricultural University
SL	Soluble liquid
SP	Soluble Powder
$t\ ha^{-1}$	Ton per hectare
WP	Wet able powder
YLCV	Yellow Leaf Curl Virus

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Miller) is one of the most important vegetable crops grown throughout the world under field and greenhouse conditions. Its belongs to the family Solanaceae and is believed to have originated in the coastal strip of western South America, from the equator to latitude of about 30^0 South (Salunkhe *et al*., 1987). Indeterminate and determinate types of plant are found in this family, where the former produces three nodes between each inflorescence with the later having fewer than three nodes, terminating in an inflorescence (Jones, 1999). This plant is adapted to a wide variety of soil and climate. Tomato production has been reported from 144 countries including Bangladesh. The top five leading tomato-producing countries are the United States, China, Turkey, Italy and India (FAO STAT Database, 2004).

In terms of human health, tomato is a major component of daily diet in many countries and constitutes an important source of minerals, vitamins and antioxidants (Grierson and Kader, 1986). Its food value is very rich because of higher contents of vitamin A, B and C including calcium and carotene (Bose and Som, 1990). The edible fruit has a range of uses in fresh and processed form. In general, it is used as salad in raw state and a number of processed food items namely soups, juice, ketchup, sauce, conserved puree, paste, powder and other products. The taste, color and flavor of tomato make it a popular culinary worldwide.

Bangladesh produced 281.56 thousand tons of tomato in 25.627 thousand hectares of land during the year 2012, average yield being 10.98 t ha^{-1}, which is very low compared to the other tomato producing countries, such as India (22.17t ha^{-1}), China (54.97 t ha^{-1}), Japan (66.34 t ha^{-1}) and USA (96.96 t ha^{-1}) (FAO STAT Database, 2014). Although area harvested and production per unit

land is increasing day by day in our country it is far behind the demand that remains throughout the year in home and international market.

Tomato has a great demand throughout the year, but its production is concentrated during the month from January to March in our country. The non-availability of tomato during summer and rainy seasons in Bangladesh is mainly because of prevailing high summer temperature (Abdalla and Verkerk, 1968).

Growing tomato is not an easy task since the plant is exposed to many constraints (diseases, climate, nutrition, etc.), while the fruit itself has to meet certain market requirements. Three factors drive consumers' preference: physical appearance (color, size, shape, defects and decay), firmness and flavor. Out of this three, appearance has the most immediate and profound effect on consumer choice.

Hybrid Tomato varieties have higher yield potential over inbred tomato varieties but hybrid varieties have certain limitations. Bangladesh Agricultural Research Institute (BARI) has released a number of yield promising inbred as well as hybrid tomato varieties such as BARI Tomato-2, BARI Tomato-4, BARI Tomato-14, BARI Tomato-15, BARI Hybrid Tomato-5, BARI Hybrid Tomato-6 etc., but their performance in different growing seasons have not been well studied. Tomato is a thermo-sensitive plant and its climatic adaptability would vary among the hybrid and inbred varieties. So, the adaptation of hybrid tomato varieties for their proper growth and development in the winter would vary in comparison to inbred varieties. The first experiment of this research work was undertaken to determine morpho-physiological and yield attributes of both hybrid and inbred tomato varieties in the winter season**.**

Tomato is a heat sensitive plant. Its high level of sensitivity to climatic factors limits year round production of tomato in Bangladesh. Bangladesh Agricultural Research Institute (BARI) released a number of heat tolerant varieties and they recommended some varieties like BARI Hybrid Tomato-4 that can be

cultivated in summer season without application of PGRs (BARI Database, 2014). So far, no experiment has been carried out in this experimental location (SAU farm, Dhaka and around) to find out performance of summer and winter tomato varieties in summer season. Therefore, the second experiment was conducted to investigate the performance of those varieties in the summer season.

Considering the above mentioned points the experiments were conducted to achieve the following objectives:

i. To investigate the variation among morpho-physiological and reproductive characteristics of hybrid and inbred tomato varieties in winter season.
ii. To determine the performance of those varieties in both summer and winter seasons.

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the most important vegetable crops grown under field and green house condition. This fruit vegetable received much attention of the researchers throughout the world because of its various ways of consumption and nutritional value. Scientists are working continuously with crops for development of new varieties and improvement of production techniques. Their findings suggest that growth and development of tomato plants largely depend on the growing season (planting time) and variety. Large number of researchers has studied the effect seasonal variation (planting time) and variety on the morpho-physiological, yield attributes of tomato in different countries of the world, but their findings have little relevance to the agro-ecological situation of Bangladesh. However, the available research findings in this connection over the world have been reviewed in this chapter under the following headings.

2.1 Influence of growing season (planting time) on tomato

An experiment was conducted by Ahammed *et al.* (2009) at Jessore to observe the effect of planting date and variety on the yield of late planting tomato. The potentiality of fruiting in the late season were evaluated for BARI tomato 4, 5, 6 and 12 by planting December 01, December 16, January 01, January 16 and February 01. A combination of December 01 planting with BARI Tomato 5 variety performed better in respect of yield (57.07 t ha^{-1}). The variety BARI Tomato 5 also showed potential fruiting capability during late winter season and February 01 planting produced 11 t ha-1 of potential yield. All the four varieties showed potential fruiting capability during late winter season and February 01 planting produced 4-6 tons of potential yield during late season.

An experiment was conducted by Hossain *et al.* (2004) to study the effect of different planting date and variety on the extension of picking period of tomato at

the Horticulture Farm, BAU, Mymensingh during 2000-2001. Yield and yield contributing characters were best in October 25 planting. The highest yield of tomato (86.40 t ha^{-1}) was obtained from October 25 planting, compared to the lowest (16.8 t ha^{-1}) from February 24 planting. The variety BARI Tomato 7 produced the highest yield (57.02 t ha^{-1}) and BARI Tomato 5 produced the lowest yield (51.38 t ha^{-1}). All the parameters showed negative response to the delay in planting.

An investigation was carried out at Joydebpur, Gazipur to determine the optimum time of planting for BARI developed hybrid tomatoes, during summer (BARI, 1998). There were four dares of planting, namely, 15 May, 15 June, 15 July and 15 August, and :- three tomato varieties, namely, TM 0836, TM 0831 and TM 0832. It was observed that, planting time did not result any significant variation on the plant characters, except TSS. However, the maximum yield was found, when the crop was planted on 15 August. On the- contrary, TM 0832 was the highest yielding hybrid (59 t ha^{-1}), which was significantly different from other hybrids.

The optimum sowing time for producing off-season tomatoes (cv. House Momodaro) in highland areas of Korea Republic was investigated by Jang *et al*. (1997). Seeds were sown on 25 June, 15 July and 15 August. Time from sowing to anthesis was 25, 13 and 12 days for the June, July and August plantings, respectively. Fruit weight for the June and July plantings was 182-194 g. Marketable fruits were produced primarily between September and October for June plantings and between October to November for July and August plantings. Marketable yield during the off-season (October-November) was highest (42.74 t ha^{-1}) for plants sown July.

Sharna and Tiwari (1996) carried out an experiment in India during 1989-90 to study the effect of planting time on yield and yield contributing characters of tomato. They reported that, transplanting on 13 February resulted in greater

percentage of fruit set (82.23%) and number of fruits per plant (48.70) than transplanting on 5 or 25 March. But individual fruit weight, diameter and total and marketable yields were greater with transplanting on 5 March.

The effect of planting time and spacing on the growth and yield of three tomato cultivars (Solan Gola, Money Maker and Naveen) was studied in Himachal Prodesh of India. Result found that, close spacing and early planting increased harvest duration. The yield was not significant affected by planting time and spacing. Naveen had the largest fruits (83.2 g) and produced the highest yield (44.1 t ha^{-1}) than others (Bhardwaj *et al.,* 1995).

Drost and Price (1991) while investigating the effect of planting date and tillage system on the growth and yield of tomato (cv. VC 82) at Michigan State USA, and reported that, planting date had no lasting effect on plant height, but late planting (2 June) led to fewer flower trusses than early planting (7 May). Late planting reduced the number of fruit and yields, but increased the weight of fruit compared to early (7 or 19 May).

The influence of planting time on the yield and fruit characters of tomato was studied by Kadam and Deore (1990) to in India. Result found that, tomato planting on 15 November produced the highest yield (0.911 kg $plant^{-1}$). Similar result was also obtained in another experiment conducted by Kadam *et al.* (1990).

The vegetable section of Bangladesh Agricultural Research Institute (BARI, 1989) reported that, 15 November planting produced significantly higher tomato yield (68.68 t/ha), followed by 1 October (35.82 t ha^{-1}) and 1 January (5.44 t ha^{-1}) planting. The maximum number of fruit (21) as well as maximum (1.85 kg) yield of fruits per plant. The minimum number (5 fruits $plant^{-1}$) and weight (0.19 kg $plant^{-1}$) of fruits in plants obtained from 1 January planting were possibly due to adverse effect of high temperature of fruit setting.

Hoque and Rahrnan (1988) conducted an experiment at Bangladesh agricultural Research Institute Farm, Joydebpur, Gazipur, to study the performance of some promising tomato lines at different planting dates. They reported that, earlier planting produced tallest plant with height number of flowers, fruits as well height yield than delay planting.

Ravikumar and Shanmugavelu (1983), while investing into the effect of different panting method and sowing time on yield and quality of some tomato varieties. They found that, the number of fruits per plant and mean yield per plant decreased with delay in sowing date. Similar results were also reported by Dayan et al. (1978). They indicated delayed planting reduced over all yields.

Maeso (1982) observed that, when tomato seeds were sown in the nursery on 17 September, 6 October, 25 October and 12 November and transplanted on 1 November, 21 November, 6 December and 21 December, respectively, the yield was maximum at the first sowing date. Similar results were also reported by Nandpuri *et al.* (1974). They found that November planting gave by far the best yield.

Abrams and Julia (1979) reported that, date of planting had a significant effect on yield and number of marketable tomatoes. The highest yield was obtained from January, intermediate yield from November and March and lowest yield from July, September and May planting.

Adelana (1977) reported that, the earliest planting resulted in greater leaf area, higher yield and number of fruits per plant and greater average fruit weight than later planting.

An experiment was conducted by Tongova and Zhekev (1975), to study the effect of sowing date and age of transplanting on growth and yield of tomato in Bulgaria. Result found that sowing date and age of transplanting had a tremendous effect on growth and yield of tomato. The authors reported that both early sowing and early

planting gave increased yield. The highest yields were produced by sowing on 20 September and transplanting at 4-5 leaf stage.

Popovic (1977) mentioned in report that, sowing date influenced the duration of developmental phases and total growth period of tomato varieties. Mid April was found to be the optimum time for planting tomato in Yugoslavia. On the other hand, Zakoyan (1974) reported that, the highest yield was obtained from plants transplanted on 20 April. The sowing date affected the maturity and yield of tomato significantly Popovic (1975).

2.2 Effect of variety on growth and reproduction of tomato

Hamid *et al.* (2005) carried out an experiment to study the performance of five Russian (Raickoi Naclazdenie, Belai Nalev, 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, where as minimum number of branches and fruit weight per plant noted in Local Kashmir. Varieties Ceberckoi ekorocepali and Patris gave maximum fruit weight of 4.96 and 4.85 kg plant^{-1} compared to the minimum of 1.60 kg plant^{-1} by local check and Novichok. Exotic varieties Patris and Ceberckoi ckorocpali are recommended for commercial Cultivation due to high production.

Rashid *et al.* (2000) carried out an experiment to evaluate thirty seven tomato varieties or lines for resistance to bacterial within the sick bed in replicated trial. Result found that, 26, 66, 33.33 and 30% incidence of wilt in BARI Tomato-4, BARI Tomato-10 respectively.

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 per 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.

The floral characteristics of heat-tolerant and heat sensitive tomato cultivars at high temperature was studied by Lohar and Peat (1998) in Nepal. They observed that, flowering was earliest in Pusa Ruby at 28-23° C (day/night) and latest in CL-1131 at 15/10° C. They also indicated that, cv. CL- 1131 was suitable for cultivating at high temperature and producing an earlier crop. Cultivar Pusa Ruby produced fewer flowers and fruits at high temperature than CL-1131, but not in 15/10° C regime.

An experiment eriment was conducted with two summer tomato varieties (BINA Tomato-2 and 3) to study the yield performance at 3 locations (Magura, Comilla and Khulna) during the summer season (BINA, 1998). It was observed that, BINA Tomato-2 produces higher fruit yield at Magura (38 t ha^{-1}) and Khulna (17 t ha^{-1}), while BINATomat-3 gave higher yield (29 t ha^{-1}) at Comilla. However, mean fruit yield from three locations showed that, the variety BFNA Tomato-2 produced higher fruit yield than BINA Tomato-3.

Singh and Sahu (1998) conducted a field experiment at Keonjhar, Orissa, India during *robi* 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^{-1}) closely followed by BT 17, PED, BT14, Sel 120, BT 1 and punjab Chhuhara. The variety Sel 120 had the highest weight and girth of fruit, whereas Punjab chhuhara produced the maximum number of fruit per plant and took less time to mature. The variety Arka Alok was earliest and large fruits.

Ajlouni *et al.*(1996) conducted a field trial in Jordan 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 F1, 898 F1 and GS12F1) 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

Berry *et al.* (1995) conducted an experiment at Wooster, USA with the hybrid processing tomato Ohio Ox 38. It was observed that, the yields of this variety in 1992 and 1993 were higher (70.3 and 80.4 t ha^{-1}, 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-23l2) in 1990 and 1992. Mean annual yield was highest in Punjaab 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).

Kallo (1989) worked with some tomato varieties (Pusa Early Dwarf, HS 102, Hisar Arun (Sel 7) And Punjab Chhuhara) in northern India. Result found that, HS 102 and Punjab Chhuhara were fit for summer cultivation, and Pusa Early Dwarf and Hisai Arun were suitable for getting early fruits

Ahamed *et al.* (1986) assessed eight F-7 lines of tomato at the Horticulture Farm, Bangladesh Agricultural University, Mymensingh. All the lines had shown indifference 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^{-1}), followed by 0013-52-10-27-32-0 (50.0 t ha^{-1}).

Hossain and Haque (1984) carried out an experiment 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^{-1}), indicating that the variety could tolerate heat and high humidity of Bangladesh better than the other two varieties.

Sarker and Haque (1980) carried out an investigation to compare the yielding ability and to assess the distinguishing external morphological characters of seven varieties of tomato during the period from October 1977 to March 1978. The varieties were Master No. 2, Ramulas, Roma, Rambo, Marmande, Bigo and World Champion. They reported that, the Rambo produced the highest yield (28.28 t ha^{-1}) followed by Bigo (24.63 t ha^{-1}), World Champion (23.38 t ha^{-1}), Master No. 2 (21.98 t ha^{-1}), Roma(21.03 t ha^{-1}) and Ramuas (20.21 t ha^{-1}).

Thomas *et al*. (1979) conducted an experiment in India with some tomato varieties to study the yield and fruit characters. They reported that dwarf money maker was the highest yielder (50 t ha^{-1}) and having the longest fruiting period. The cultivar V. 687 and Parc-5 also gave higher yields than Gaamed, Punjab Chhuhara and Roma.

Prasad and Prasad (1977) carried out an experiment with 8 varieties tomato in India. The highest yield was obtained from Kalyanpur Angurlate followed by kolyanpur T1 and Sioux. The Kolyanpur T1 had the highest fruit.

Hossain and Ahmad (1973) conducted a varietal trial at the Bangladesh Agricultural Research institute, Joydebpur. There were six tomato varieties, namely, Roma, Bulgaria, USA, Anabik, Oxheart and Sanmarzano. They observed that, cv, Sanmarzano was the height yielder (28.98 t ha^{-1}), followed by Oxheart, Roma, Bulgaria, USA, Anabik.

In 1969-70, a yield trial was conducted with five varieties of tomato (Oxheart, Sinkurihara, L-7, Margiobe and Bulgaria) at the Vegetable Division of

Agricultural Research Institute, Dhaka. The experiment was repeated in 1971-72. In both years, the varieties Qxjieart and Sinkrihara were found to be similar and significantly higher yielder than the other (Hoque *et al*., 1975).

2.3 Combined effect of variety and growing season on tomato

Das *et al.* (2011) conducted a field experiment variation in growth and yield quality of tomato varieties under different showing time. Result found that BARI Tomato-2 (Ratan) performed the best in yield in association with November 09 planting.

Hossain (2001) conducted an experiment at the Horticulture Farm, BAU, Mymensing with four tomato varieties namely BARI Tomato-4, BARI Tomato-5, BARI Tomato-7, BARI Tomato-8 and three planting dates (October -25, December-25, and February-24).Planting dates and varieties had significant influence on growth, yield contributing parameters and yield of tomato. The highest yield of tomato (86.40 t ha^{-1}) was obtained from October 25 planting compared to lowest in Tomato-7 gave the highest yield (100.13 t ha^{-1}) in October 25 planting.

Nessa *et al.* (2000) conducted an experiment to study the comparative performance of ten genotypes of tomato in late planting and reported that the genotype BAU/TM 0058 was the best in late planting. It was closely followed by BAU/TM 0041. They also state that, fruit number and fruit weight should be considered as important criteria for higher yield.

Islam (2000) conducted a field experiment with four dates of planting (16 October, 15 November and 14 January) and four varieties (BINA Tomato-2, BARI Tomato-3, BARI Tomato- 4, BARI Tomato- 5 at the horticulture farm, BAU, Mymensingh during the period from September, 1999 to May, 2000, to extend the pocking period of tomato through selection of variety and adjustment of date of planting. He mentioned that, the highest yield of tomato (53.65 t ha^{-1}) was achieved from 16

October planting. The variety BARI tomato-3 produced the highest yield (50.65 t ha^{-1}) and BINA Tomato- 2 gave the lowest yield (34.80 t ha^{-1}).

Phookan *et al.* (1997) while working with seven tomato cultivars (BTI, Arka Alok, LE79, VC 48-1, Best of All, Arka Abha and AC 238), mentioned that, the varieties were planted in March and July under a plastic cover at Jorhat, Assan, India. The maximum fruit set of 27.85% was observed in BTI in the March planting and 22.38% in AW July planting.

Hanson *et al.* (1996) conducted a field experiment to assess the seasonal variation in fruit yields among 22 determinate tomato inbred lines (commonly grown in low land and Mid-elevation areas of southwest Asia) grown during the simmer and a dry season at Los Banos, Philippines and Kamphaengsaen, Thailand. The lines, MTi, Mapula and CL 5915-93D4-1-0-3 performed well in both seasons, although they had small fruits. Marikit had the highest mean yield in both locations in the dry season, but did not perform well in the summer season.

Singh and Tripathy (1995) conducted a field experiment at Regional Research Station, Orissa, India during the rainy season of 1992 to study the growth and yield of four tomato genotypes (Pusa Ruby, LE79, BT1 and Arka Alok). The cultivars showed significant genotypic variation for vegetative growth, fruit characters and yield when sown on different dates (20 June, 5 and 20 July and 5 and 20 August). The line LE97 gave the highest fruit yield (12.2 t ha^{-1}) and Arka Alok produced significantly larger fruits (20.3 cm in diameter and 136 g in weight).Sowing on 20 June was significantly favorable for fruit yield as well as its contributing characters, like fruits weight (60.8 g), length (9.8cm) and girth (16.2 cm)..

A field Experiment was conducted by Jamwal *et al.* (1995) at the Regional Research Station, Baj aura, India during the summer of 1990 with two tomato cultivars, Roma and Sioux. The varieties were planted on 20 April and 20 May.

They reported that, yield per hectare was similar for both cultivars; Roma produced significantly more fruits per plant, but had lower individual fruit weight than Sioux. Planting on 20 April gave better result than later planting.

An experiment was carried out by Phookan and Shadeque (1995) at Jorhat, Assam, India in order to test different genotypes of tomato during 4 seasons, Viz. early spring, spring, summer and autumn. Out of 29 genotypes, 7 were common in all the 4 seasons. The authors reported that the crop planted in September gave the highest yield, being 91.10, 74.66 and 67.88% higher than that planted in May, July and March, respectively. Among the varieties, the highest yield was recorded in Arka Abha (1.5 kg plant^{-1}) followed by Arka Alok.

Marglobe and Taleb (1994) conducted an experiment to study the effect of planting time (15 November, 30 November and 15 December) growth and yield of tomato at the horticulture farm of Bangladesh Agricultural University, singh. He found that November 15 planting produced the tallest plants (129 m) and maximum yield per plant (4.29 kg), which was statistically different from other dates of planting.

Akhter (1993) carried out an experiment at the regional Agricultural Research n, Ishurdi, Pabna during the period from February to July 1992 to study the effect of different doses of NAA and planting dates (1 March and 1 April) on two heat tolerant tomato advance lines (TM 0111 and TM 0367). He observed that, March planting produced significantly higher yield (21.45 t ha^{-1}) than April planting (7.81t ha^{-1}). The yield of TM 0111(15.05 t ha^{-1}) was higher than TM 0367 (14.22 t ha^{-1}), but that was not statistically significant.

Reddy *et al.* (1989) carried out an experiment for screening of tomato germplasms suitable for summer cultivation in North Indian conditions. For this, they followed early and late plantings during March 1981. They observed that, two types in early planting, two in late planting and one in both planting were earliest of all the

genotypes. One accession, Shift had produced commercially acceptable fruit in the first planting. In the second planting, all the accessions showed very poor performance with respect to fruit setting, weight and yield.

In another experiment, conducted at the Vegetable Section of Bangladesh Agricultural Research Institute (BART, 1986) with some tomato lines planted at different dates, larger fruits were obtained from late planting. It was also noticed that, tomatoes when planted early in October or November required more time to mature an planted in January.

Hossain *et al.* (1986) conducted an experiment with 15 tomato lines in the grey flood plain soils of the Regional Agricultural Research Station, Jamalpur during the period 1983-84 to study the performance of some tomato lines sown at different dates (2 Sep. 2 Oct. and 2 Nov.). They reported that, November was the best time for sowing tomato seed in seed beds as compared to October or September sowing. The line TM U367 gave significantly higher yield (52.2 t ha^{-1}) than other lines. They also reported that, early November sowing gave significant higher yield than September or October Sowing. The results in general are in agreement with the findings of a study Conducted at Joydebpur (Hoque, 1983). The line TM 0367 produced significantly higher yield (54.2 t ha^{-1}) than other lines under study.

Bhuya and Haque (1983) conducted an varietal trial at the Agricultural Research Sub-station, Pahartali, Chittagong to evaluate tomato varieties for winter and summer cultivation conducted. They observed better performance of all the varieties in winter season, while only five varieties survived in the summer season under the excessive rainfall. In the winter season, the yield, however, appeared statistically similar amongst the varieties. However, of the two seasons, yield in summer was lower. The result further suggested that, there were specific genotypes for summer cultivation here in Bangladesh.

2.4. Overall review

Taleb (2003) studied that plant height and length of leaves of the vegetables increased gradually with the decrease of light levels. Uthpol (2004) conducted an experiment to select the suitability of the two vegetables (tomato & radish) for agroforestry system. He showed that yield of the vegetables decreased gradually with the increase of the shade levels.

Rahman et al. (2004) reported that except plant height all others morphological characters viz., no. of branches plant-1 , no. of fruit plant^{-1}, Fruit length, fruit diameter and fruit weight of three vegetables (tomato, brinjal and chilli) were highest in open field condition.

Hanada (1990) conducted an experiment under 8 levels of shading (0, 20, 37, 48, 50, 72, 87 and 98 percent) in radish, kangkong, cucumber and tomato. He reported that shading decreased soil temperature, preserved soil moisture and prevented insect attack. Shading increased yields in kangkong and cucumber with 20 percent and 37 percent shading but decreased yields in radish and tomato with increasing amount of shade levels.

Cockshull et al. (1992) carried out an experiment fewer than two shade treatments (light shade and heavy shade) in tomato plants and reported that both two-shade treatments reduced the total fresh weight yield of fruit by 7.5 and 19.95% and the estimated total above ground biomass by 6.2 and 16.5% respectively. Shading reduced average fruit size and also reduces the proportion of fruit in the larger size grades. Heavy shade also reduced the incidence of uneven ripening in summer.

Nasiruddin et al. (1995) reported that shading increased plant height, the tallest plants were those of Marglobe (157.82 cm) in complete shade treatment (black polythene shade) and the shortest was Rama VF controls (83.38 cm) in natural light (no shade). The number of fruit per plants decreases with the increase of shading. But fruit size was greatest and colour was brightest under partial shade

(coconut leaves shade). Shading decreased yields of Rama VF and Marglobe from 2.593 and 2.383 kg/m2, respectively in controls to 2.303 and 2.114 kg/m2 respectively.

Leonardo (1996) observed that shading (60% light reduction) reduced vegetative and fruit growth. Shading increased plant height shading also reduced chlorophyll content. Stomata density, transpiration rate and photosynthesis rate, yield of peppers decreased with increasing amount of shade levels.

Zheng and Li (1998) found that saplings of 8 tomato cultivars in a greenhouse were shaded to 20% of natural light for 14 days. Shading decreased dry weight by 30.98 to 74.33% with the 10 smallest effect in cv. 1239-F 2121-0. This cultivar showed no effect of shading on specific leaf weight was decreased by up to 40.03% and the leaf area by up to 32.21 %. Shading increased plant height decreased plant dry weight at flowering.

Shade has pronounced effect on morphological characters of many crops. It influences plant height, stem diameter, internodes length, number of primary branches per plant, leaf number per plant, leaf size, thickness and leaf area etc. plant height increases gradually with the decrease of light levels (Ali, 1999).

From the above mentioned review it appears that the growing season (planting time) and varieties play an important role on the growth, yield and yield contributing characters of tomato in a particular location. The planting time and variety may have variable effects on the morpho-physiological attributes of tomato depending upon climatic condition, geographic location, seasonal variation, and cultivation practices. The present study will be conducted to study the response of tomato varieties to seasonal variation specially during summer which will help to farther improvement tomato variety that will be better fitted to its environment with shameless yield performance.

CHAPTER III

MATERIALS AND METHODS

The study was comprised of two pot experiments. The experiments were conducted at the successive winter (*Robi*) and summer (*Kharif-1*) seasons of 2013-2014, under normal and transparent polythene shade conditions, respectively. Materials used and methods followed during the course of study have been mentioned in this chapter under the following heads and sub-heads.

3.1 Experimental sites

3.1.1 Location

The experiment was carried out at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.

3.1.2 Geographic location

Geographically the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 is located at $23^0 77'$ N latitude and $90^0 37'$ longitude at an altitude of 9 m above the sea level (BCA, 2004), which belongs to the Madhupur Tract in the agro-ecological zone of 28 (AEZ-28).

3.2 Growth environment

3.2.1 Soil

The soil of both experiments was collected from Savar river site during the month of October 2013. The soil texture was sandy loam and pH was 6.0-6.4.

3.2.2 Climate

Both the experiments were carried out in the same place. The experimental site was characterized by scanty rainfall associated with moderately low temperature during October to March (*Robi* season), and high temperature with high relative humidity and medium rainfall with occasional gusty winds in April to September (*Kharif* season). The meteorological data during the

experimental period (November 2013 to October 2014 for Dhaka) were presented in the appendix II**.**

3.3 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 BARI Tomato-2, BARI Hybrid Tomato-4, BARI Hybrid Tomato-5, BARI Tomato-14 and BARI Tomato-15. All the varieties are semi-indeterminate type except BARI Tomato-15 (determinate). The seeds were collected from the Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI) at Joydebpur. A short description of the plant materials used is given below (BARI Database, 2014).

3.3.1 BARI Tomato-2

It is a high yielding variety developed by BARI in 1986. It is recommended for cultivation in *Rabi* season. The variety is tolerant to BW (bacterial wilt), fruits are round and red in color, average fruit weight 85-90g with a good shelf life. Crop duration takes from 120 to 130 days. It gives fruit yield of 85-90 t ha^{-1}.

3.3.2 BARI Hybrid Tomato-4

It is a hybrid variety developed by BARI in 2006. It is recommended for cultivation in *Kharif* season. The variety is heat tolerant and can be cultivated during *Kharif* season without application of hormone. Crop duration is up to 100 days, average fruit weight is 50 g and it gives a fruit yield of 40-45 t ha^{-1}.

3.3.3 BARI Hybrid Tomato-5

It is a hybrid variety developed by BARI in 2008 and is recommended for cultivation in *Rabi* season. The variety is high yielder and tolerant to BW and YLCV. Fruits are large round and red in color, and average fruit weight is 90-95g. Crop duration is 120-130 days and it gives fruit yield of 95-100 t ha^{-1}.

3.3.4 BARI Tomato-14

It is a high yielding variety developed by BARI in 2007. It is recommended for cultivation in early and late *Rabi* season. The variety is tolerant to BW (bacterial wilt) and TYLCV. The fruits are semi globe and flesh red in color with an average fruit weight of 90-95g and good shelf life. Crop duration is up to 130 days and it gives fruit yield of 85-90 t ha^{-1}.

3.3.5 BARI Tomato-15

It is a high yielding variety developed by BARI in 2009. This variety has determinate type of growth habit. It is recommended for cultivation in *Rabi* season. The variety is tolerant to TYLCV. The fruits are obovoid shaped and average fruit weight is 65-70 g with a good shelf life. Crop duration is 110-120 days and it gives fruit yield of 80-85 t ha^{-1}.

3.4 The Experiments

Expt. 1. Performance of some hybrid and inbred tomato varieties during winter season

Expt. 2. Performance of some hybrid and inbred tomato varieties during summer season

3.4.1 Treatments of the experiments

Both the experiments consisted of one factor, *viz*. tomato varieties.

Following five BARI tomato varieties were collected from Bangladesh Agricultural Research Institute (BARI):

i. BARI Tomato-2 (Ratan)
ii. BARI hybrid Tomato-4
iii. BARI hybrid Tomato-5
iv. BARI Tomato-14
v. BARI Tomato-15

3.4.2 Design and layout of the experiments

Both the experiments were carried out in same design and layout. These were pot culture experiments. The design used was Randomized Complete Block Design (RCBD) with four replications.

3.4.3 Pot preparation

Earthen pots were used. At first the pots were sun dried. Sandy loam soil and cowdung were mixed and pots were filled with this soil 7 days before transplanting. Weeds and stubbles were removed from the soil. The pH of the soil was 6.0 to 6.4.

3.4.4 Manure and fertilizer application

Manure and fertilizers were applied as per recommendation of Bangladesh Agricultural Research Institute (BARI) for poor soil. Cowdung @ 15 t ha^{-1}, TSP @ 250 kg ha^{-1} and MP @ 260 kg ha^{-1} were applied during pot preparation (BARI, 2014). Furadan 10 G (an insecticide) @ 0.25 g pot^{-1} was also applied during final pot preparation to control soil insects.

3.4.5 Raising of seedlings

Tomato seedlings were raised in a seedbed of 2 m x l m size. The soil was well prepared and converted into loose friable and dried mass by spading. All weeds and stubbles were removed and 5 kg well rotten cowdung was mixed with the soil. The seeds were sown in the seedbeds in October 20, 2013 and March 20, 2014 for winter and summer planting respectively. 0.5 gram of seeds of each variety was sowed on seedbed by means of two lines for each variety. After sowing, edges were covered with light soil. 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 within 4 to 7 days. Shading by polythene with bamboo structure was provided over the seedbed to protect the young seedlings from the scorching sunshine or rain. Dithane M-45 @ 2 g

L^{-1} was sprayed in the seedbeds, to protect the seedlings from damping off and other diseases. Weeding and irrigation were done whenever necessary.

3.4.6 Transplanting of seedlings

Healthy and uniform 30 days old seedlings were uprooted separately from the seedbed and two seedlings were transplanted in each experimental pot at the afternoon of November 20, 2013 and April 20, 2014 during winter and planting respectively. The seedbed was watered before uprooting the seedlings in order to minimize damage of the root system. The seedlings were watered just after transplanting. Shading was provided using banana leaf sheath for four days to protect the seedling from the hot sun. After 10 days, one healthy seedling out of two was allowed to grow and one was discarded from the pot.

3.4.7 Intercultural operations

3.4.7.1 Shading

A transparent polythene shade was provided to protect the plants from excess rainfall of monsoon. It was made with the help of polythene sheet and bamboo sticks just after the establishment of seedlings on pots. The shade was maintained up to final harvest (110 DAT).

3.4.7.2 Weeding

Weeding was accomplished as and when necessary with the help of *khurpi* to keep the crop free from weeds, for better soil aeration and to break the crust. It also helped in soil moisture conservation.

3.4.7.3 Irrigation

Irrigation was provided immediately after transplanting the seedlings and it was continued until the seedlings were established in the pot. As it was a pot experiment a high frequency of irrigation were demanded. Usual irrigation schedule for field grown tomato was not followed. Irrigation was provided each alternate day in general but sometimes the plants demanded everyday

irrigation. During the month of June, July and early August irrigation was provided 3 to 4 days interval due to prevailing of high relative humidity (RH).

3.4.7.4 Stalking

As tomato is a herbaceous plant with higher fruit weight it was needed a high level of support at its growth and developmental stages. So, after the well establishment of the plants, staking was done to each plant by means of bamboo sticks to keep them upright.

3.4.7.5 Plant protection

Furadan 10 G an insecticide @ 0.5 g pot^{-1} was applied during the filling of pots to control cut worm and other soil insects. Aphid a leaf sucking insect infested the crop at vegetative and early reproductive stage, which was controlled by Emitaf 20 SL @ 0.25 ml L^{-1} of water at 7 days interval for three weeks. During the summer season, white fly infested the crop at early reproductive stage, which was controlled by means of spraying with Admire 200 SL @ 0.5 ml L^{-1} of water at 7 days interval for 2 weeks.

3.4.8 Harvesting

Harvesting of tomato during winter (November 20, 2013 transplanting) was started from February 18, 2014 and was continued up to March 30, 2014. During this season, fruits were harvested at 5-days intervals at ripening stage when they attained slightly red color. During the summer season, no harvesting was required due to complete flower dropping of BARI Tomato-2, BARI Tomato-14 and BARI Tomato-15. Although fruit setting was occurred in BARI hybrid Tomato-4 and BARI Hybrid Tomato-5 but harvesting of fruit was not carried out because of complete dropping of premature fruits of both the varieties even if BARI hybrid Tomato-4 was a recommended variety for *Kharif* season.

3.4.9 Data collection

In both of the experiments, three pots were allotted for each treatment in each plot for each replication that's why there were 12 sample plants for each treatment. Data was collected from each sample plant and mean value was calculated.

The following data were recorded.

i. Plant height (cm) at 25 DAT, 40 DAT, 55 DAT and 110 DAT (final harvest)
ii. Root dry weight plant^{-1} (g)
iii. Shoot dry weight plant $^{-1}$ (g)
iv. Total vegetative dry weight plant^{-1} (g)
v. SPAD value of leaf
vi. Days to appearance of first inflorescence
vii. Flower clusters plant^{-1}
viii. Floral buds cluster^{-1}
ix. Flowers cluster^{-1}
x. Fruits cluster^{-1}
xi. Fruit diameter (cm)
xii. Percentage of total soluble solid (% TSS) of fruit
xiii. Total number of fruits plant^{-1}
xiv. Average fruit weight (g)
xv. Fruit weight plant^{-1} (kg)
xvi. Yield (t ha^{-1})

3.5 Detailed procedures of data collection

3.5.1 Plant height

Plant height was recorded at 15 days interval starting from 25 days of transplanting up to 55 days to observe the growth rate of plants. Finally, the height was recorded at final harvest (110 DAT). Plant height was measured

from sample plants in centimeter from the ground level to the tip of the longest stem and mean value was calculated.

3.5.2 SPAD value of leaf

SPAD meter reading of fresh leaves was recorded at 45 days after transplanting to compare relative chlorophyll content of leaves. Ten reading were taken from leaves of each sample plant avoiding the mid-rib region carefully and average value was presented as SPAD value of leaves. Higher SPAD value was considered as higher total chlorophyll (pigments) content of leaf.

3.5.3 Root and shoot dry weight plant^{-1}

After the final harvest (110 DAT) the total plant fresh biomass was collected. The shoot was collected by cutting the plant at soil level with the help of sharp knife. The root was collected by washing out soil from pot through high-pressure water flow and roots were washed in fresh water to remove soil particles and other adhesive substances. After collecting, the plant parts were sun dried and put into paper bag separately. Then the collected plant parts were oven dried for 72 hours at 70^0C. Root, shoot and total vegetative dry weight were taken with the help of an electronic balance.

3.5.4 Days to appearance of first inflorescence

The date of first inflorescence appearance of the sample plants was recorded, and the mean value of the period required in days from the date of transplanting was calculated.

3.5.5 Flower clusters plant^{-1}

Total number of flower cluster was counted from all sample plants and mean was calculated by the following formula:

$$\text{Flower clusters plant}^{-1} = \frac{\text{Total number of flower clusters from three sample plants}}{3}$$

3.5.6 Floral buds cluster^{-1}

Total number of floral buds was counted from all clusters of sample plants and mean was calculated by the following formula:

$$\text{Floral buds cluster}^{-1} = \frac{\text{Total number of floral buds from three sample plants}}{\text{Total number of clusters from three sample plants}}$$

3.5.7 Flowers cluster^{-1}

Total number of flower was counted from all clusters of sample plants and mean was calculated by the following formula:

$$\text{Flowers cluster}^{-1} = \frac{\text{Total number of flowers from three sample plants}}{\text{Total number of clusters from three sample plants}}$$

3.5.8 Fruits plant^{-1}

It was recorded by the following formula:

$$\text{Fruits plant}^{-1} = \frac{\text{Total number of fruits from three sample plants}}{3}$$

3.5.9 Average fruit weight

Among the total of harvested fruits during the period from the first to final fruits harvest, except the first and last harvests, 10 randomly selected fruits were considered for determining ideal fruit weight in gram.

3.5.10 Fruit diameter

Diameter of fruit was measured at the middle portion of 30 randomly selected fruit from three sample plants of each replication with the help of a slide calipers. The number of fruit at three arbitrary groups namely, (a) >5.5 cm, (b) 5.5-4.0 cm and (c) <4.0 cm was counted. Percentage of fruit at different diameter range was recorded by the following formula:

$$\text{Fruit of a diameter range} = \frac{\text{Number of fruits of that diameter range}}{30} \times 100$$

3.5.11 Total soluble solid (%TSS) content of fruit

ATAGO Master Refractometer was used to determine percent total soluble solid (%TSS). For each value, a ripen fruit was sliced into two halves horizontally with a sharp knife and a small quantity of juice from them was used to determine total soluble solid (%TSS) in percentage with the refractometer.

3.5.12 Fruit yield plant^{-1}

It was measured by the following formula:

$$\text{Fruit weight plant}^{-1} = \frac{\text{Total weight of fruits from three sample plants in kilogram}}{3}$$

3.5.13 Yield

The experiment was conducted in pot, so for obtaining fruit yield per hectare an ideal spacing was considered. The plant to plant and row to row distance 60 cm x 60 cm was considered for tomato cultivation under field condition. So, each plant covered 0.36 m^2 area. Therefore, yield of fruit per hectare was measured by the following formula:

$$\text{Yield (t ha}^{-1}) = \frac{\text{Fruit yield from three sample plants (kg) x 10000}}{\text{3 x Area covered by a plant in square meter x 1000}}$$

3.6 Statistical analysis

The data collected on various parameters were statistically analyzed to obtain the level of significance using the MSTAT-C (Russell, 1986) statistical computer package program. Analysis of variance was done following one factor randomized complete block design (RCBD). The mean differences among the varieties were compared by least significant difference (LSD) test at 5% level of significance. Raw data management, tabulation and graphical presentation were done by using Microsoft Office Word and Microsoft Excel program software.

CHAPTER IV

RESULTS AND DISCUSSION

The results of the study have been presented in this chapter. As already mentioned, two consecutive experiments were conducted in winter and summer seasons of 2013-2014. The varieties remained same for both the experiments and only growing seasons were different *i.e.* winter (November 20, 2013 planting) and summer (April 20, 2014). The first experiment was conducted to determine growth, yield performance of five BARI released varieties in winter season, and the second one was conducted to determined comparative quantitative vegetative and reproductive performance of the same varieties as affected by seasonal variation. Some of the data have been presented and expressed in table (s) and others in graphs for ease of discussion, comparison and understanding. A summary of the analysis of variances in respect of all parameters have been shown in the appendices, and possible interpretations wherever necessary have been presented under the following headings.

4.1. WINTER SEASON (November 20, 2013 planting)

4.1.1 Plant height at different days after transplanting

Plant height at different days after transplanting has been showed in Figure 1. Plant height is one of the most important growth parameters that indicates vegetative growth trend of plants. The varieties used for this experiment have both semi-determinate and determinate growth habit and four out of five BARI Tomato varieties were recommended for winter except BARI Hybrid Tomato-4. So, for easy understanding and comparison of vegetative growth of tomato, plant height was recorded at different days after transplanting (DAT) and at final harvest (110 DAT).

The effect of varieties on plant height was significantly varied at different days after transplanting during winter season (Appendix III). It was found that BARI Hybrid Tomato-5 produced the tallest plant at 25 DAT (31.26 cm), which was

statistically similar to BARI Tomato-2 but varied significantly with the other varieties. The BARI Tomato-14 produced the shortest plant at 25 DAT (21.40 cm) which was statistically similar to the BARI Hybrid Tomato-4 but varied significantly with the other varieties.

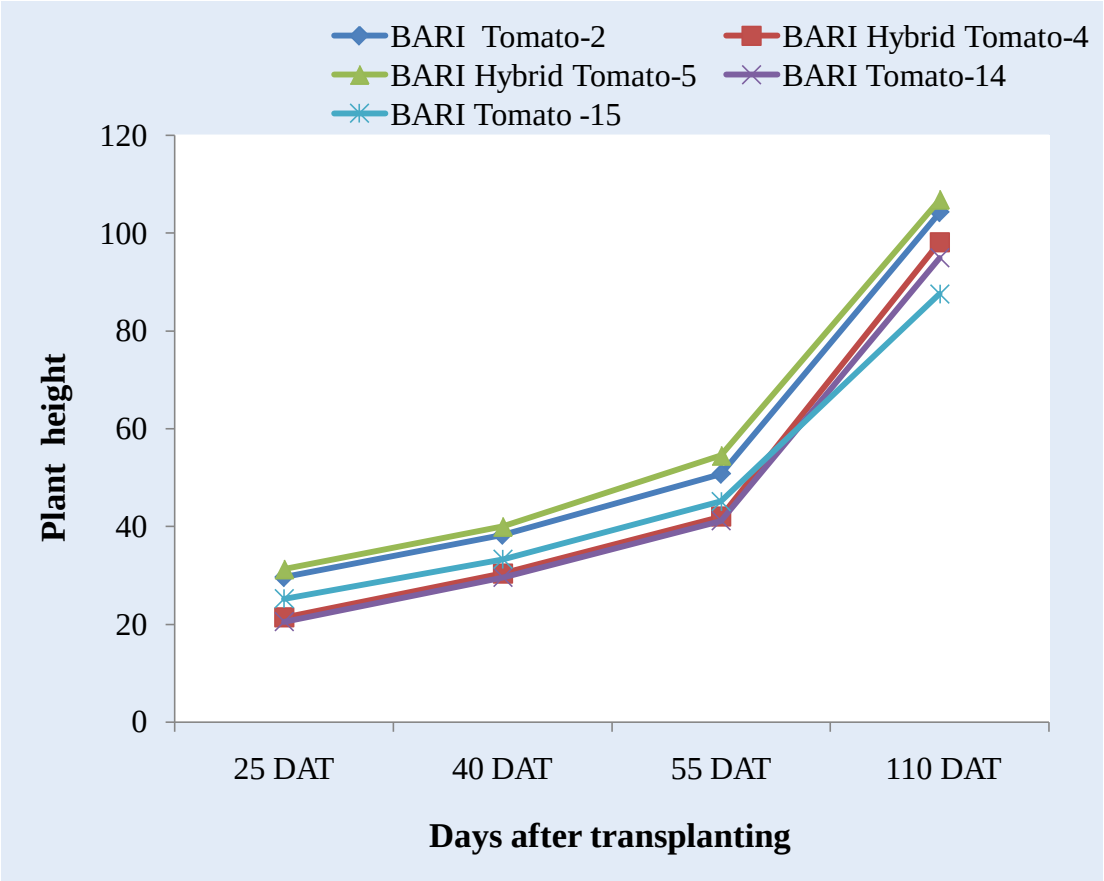

Figure 1. Effect of variety on plant height at different days after transplanting during winter season ($LSD_{0.05}$ = 2.46, 3.07, 3.46 and 4.81 at 25 DAT, 40 DAT, 55 DAT and 110 DAT respectively)

BARI Hybrid Tomato-5 produced the tallest plant at 40 DAT (39.96 cm), which was statistically similar to BARI Tomato-2 but varied significantly with the other varieties. The BARI Tomato-14 produced the shortest plant at 40 DAT (29.61 cm) which was statistically similar to the BARI Hybrid Tomato-4 but varied significantly with the other varieties.

BARI Hybrid Tomato-5 produced the tallest plant at 55 DAT (54.48 cm), which varied significantly with the other varieties. The BARI Tomato-14 produced the shortest plant at 55 DAT (41.10 cm) which was statistically similar to the BARI Hybrid Tomato-4 but varied significantly with the other varieties.

Analysis of variance also indicated that the effect of tomato varieties on plant height at final harvest (110 DAT) varied significantly during winter season (Appendix III). It was found that BARI Hybrid Tomato-5 produced the tallest plant at final harvest (106.80 cm), which was statistically similar to BARI Tomato-2. The BARI Tomato-15 produced shortest plant at final harvest (87.58 cm) which was statistically varied significantly with the other varieties (Fig. 1).

From the result of plant height at different days after transplanting and final harvest (Fig.1), it can be stated that plants of all varieties possessed a normal growth rate in winter season. It is clear that variety has significant effect on plant growth rate and they differ from each other. Growth of BARI Hybrid Tomato-5 was significantly higher in early vegetative to successive days after planting indicating its hybrid vigor over the other varieties. Although growth rate (indicated by plant height) of BARI Tomato-2 is initially a little bit slower than BARI Hybrid Tomato-5 but final plant height indicated its potential ability to grow over the growth stages up to final harvest.

4.1.2 Root dry weight

Analysis of variance showed that the effect of tomato varieties on root dry matter accumulation per plant at final harvest was varied significantly during winter season (Appendix IV).The maximum accumulation of root dry matter (1.82 g plant^{-1}) accumulation was found in BARI Hybrid Tomato-5 which was statistically similar to BARI Tomato-2, BARI Tomato-14 and BARI Tomato-15 but varied significantly with BARI Hybrid Tomato-4 (Table 1).

Root is one of the most important plant organs that facilitate plant to anchor soil and absorption of water, mineral nutrients etc. Plants develop strong root

system in order to supply water and other mineral salts for ensuring proper growth and development. From the result of statistical analysis of root dry matter accumulation per plant, it was found that relative development of root system of five BARI Tomato varieties varied significantly as influenced by variety. As like the plant height, root development of BARI Hybrid Tomato-5 was also better compared to other BARI Tomato varieties which indicating higher root growth and dry matter accumulation in root. It was also found that varietal influence on root dry matter accumulation of all the five tomato varieties were very close, it could be due to comparatively smaller growth environment of root system into the earthen pots or easy availability of soil water as provided by frequent irrigation.

4.1.3 Shoot dry weight

The variation in shoot dry matter accumulation per plant at final harvest due to the varietal effect of tomato was statistically significant (Appendix IV). The maximum accumulation of shoot dry matter (17.52 g plant^{-1}) accumulation was found in BARI Tomato-2 which was statistically similar to BARI Hybrid Tomato-5 but varied significantly with the other varieties. The minimum accumulation of shoot dry matter (9.90 g plant^{-1}) was found in BARI Tomato-15 which was statistically similar to BARI Hybrid Tomato-4 and BARI Tomato-14 but varied significantly with the other tomato varieties (Table 1).

4.1.4 Total vegetative dry weight

The effect of tomato varieties on total vegetative dry matter accumulation per plant at final harvest was varied significantly during winter season (Appendix IV). The maximum total vegetative dry matter (19.10 g plant^{-1}) accumulation was found in BARI Tomato-2 which was statistically similar to the BARI Hybrid Tomato-5. The minimum total vegetative dry matter accumulation (11.54 g plant^{-1}) was found in BARI Tomato-15 which was statistically similar to BARI Hybrid Tomato-4 and BARI Tomato-14 but varied significantly with the other tomato varieties (Table 1).

Table 1. Effect of variety on dry matter accumulation in different plant parts during winter season

Variety	**Root dry weight plant^{-1} (g)**	**Shoot dry weight plant^{-1} (g)**	**Vegetative dry weight plant^{-1} (g)**
BARI Tomato-2	1.58 a	17.52 a	19.10 a
BARI Hybrid Tomato-4	1.21 b	11.73 b	12.94 b
BARI Hybrid Tomato-5	1.82 a	16.84 a	18.67 a
BARI Tomato-14	1.62 a	10.51 b	12.14 b
BARI Tomato -15	1.63 a	9.90 b	11.54 b
$LSD_{0.05}$	0.32	2.45	2.65
CV (%)	13.25	11.96	11.58

4.1.5 SPAD Value of leaf

SPAD meter reading of leaf was analyzed and presented in order to having an idea about relative leaf chlorophyll content per unit leaf area of the tomato varieties. Analysis of variance indicated that the effect of tomato varieties on relative chlorophyll content of leaf was varied significantly during winter season (Appendix IV). The maximum SPAD value (46.20) was recorded in leaf of BARI Hybrid Tomato-5 which was statistically similar to BARI Tomato-2, BARI Hybrid Tomato-4 and BARI Tomato-14 but varied significantly to BARI Tomato-15.The higher SPAD value obtained from the former tomato varieties indicated that leaves of these varieties contained relatively higher but statistically similar amount of chlorophyll per unit leaf area compare to the later one (Fig. 2).

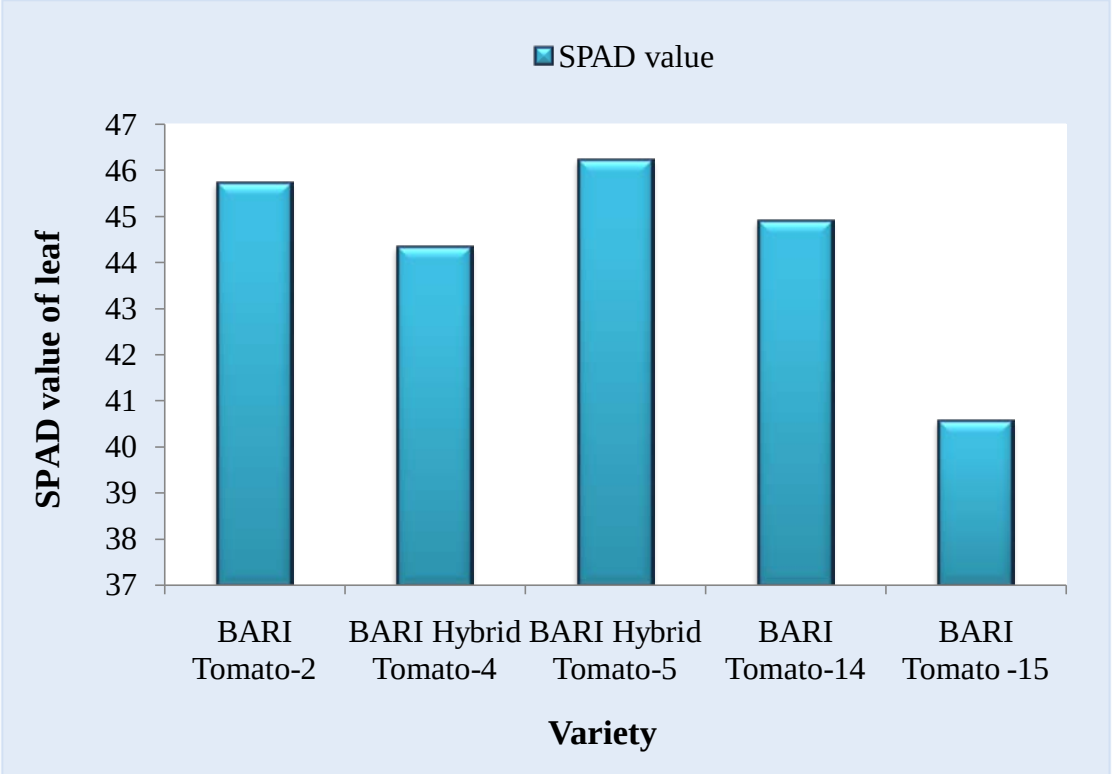

Figure 2. Effect of variety on relative chlorophyll content of leaf during winter season ($LSD_{0.05}$ = 3.73)

4.1.6 Days to first appearance of inflorescence

The time required for first appearance of inflorescence was varied significantly among the varieties during the winter season (Appendix V). It was found that BARI Tomato-2 required maximum time (29.50 days) for the first appearance of inflorescence which was statistically similar to BARI Hybrid Tomato-4 and BARI Hybrid Tomato-5. The minimum time (23.42 days) for first appearance of inflorescence was required by BARI Tomato-14, which was statistically similar to BARI Tomato-15 but varied significantly with other varieties (Fig. 3).

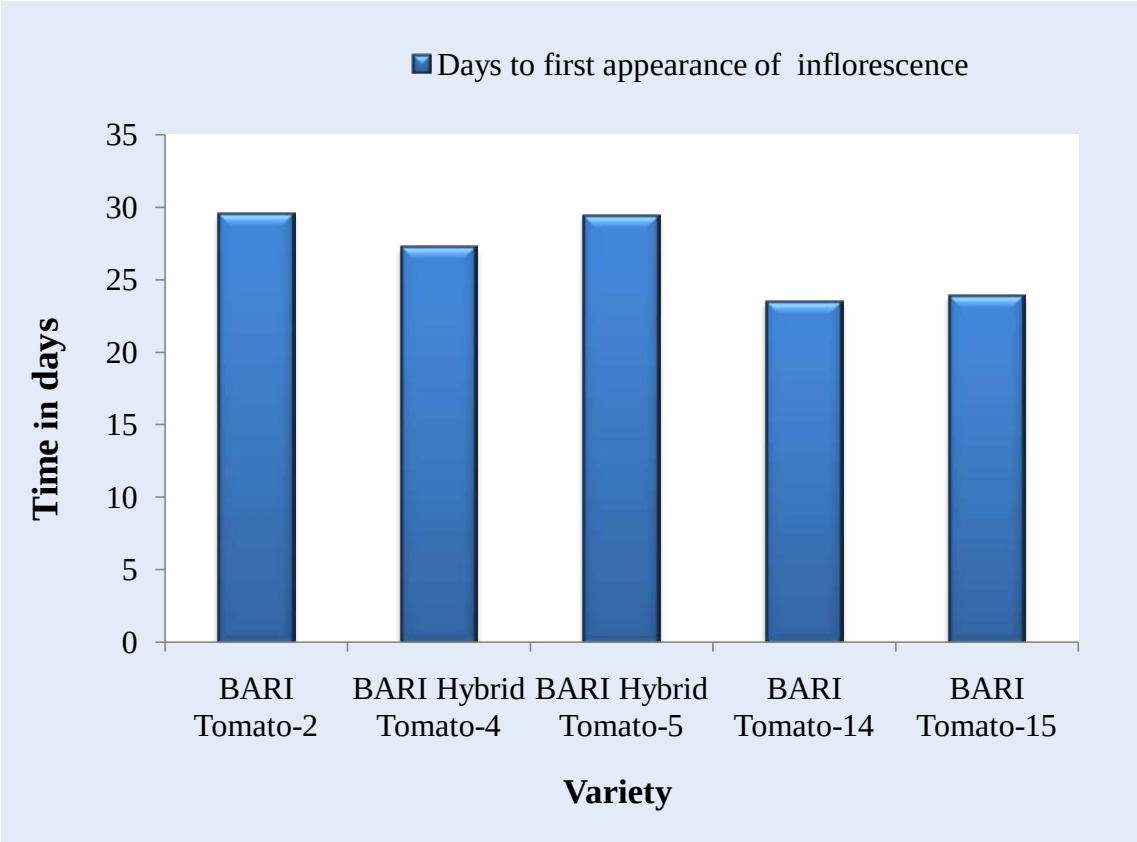

Figure 3. Effect of variety on the first appearance of inflorescence during winter season ($LSD_{0.05}$ = 2.43)

4.1.7 Flower clusters plant^{-1}

Analysis of variance indicated that the effect of varieties on flower clusters per plant was varied significantly during winter season (Appendix V). It was found that maximum flower clusters per plant (9.58) was produced by BARI Hybrid Tomato-4 which was significantly higher than the other varieties. On the other hand, minimum flower clusters per plant (6.24) was produced by BARI Tomato-2 which was statistically similar to BARI Hybrid Tomato-5 but varied significantly with the other tomato varieties (Table 2).

4.1.8 Floral buds cluster^{-1}

Analysis of variance indicated that the effect of varieties on number of floral buds per cluster was varied significantly during winter season (Appendix V). It was found that maximum floral buds per cluster (7.00) were produced by BARI Hybrid Tomato-5 which was statistically similar to BARI Hybrid Tomato-4. On the other hand, minimum floral buds per cluster (5.42) were produced by BARI Tomato-14 which was statistically similar to BARI Tomato-2 and BARI Tomato-15 but varied significantly with the other varieties (Table 2).

4.1.9 Flowers cluster^{-1}

The effect of tomato varieties showed significant variation on production of flowers per cluster during winter season (Appendix V). It was found that maximum flowers per cluster (5.31) were produced by BARI Tomato-2 which was statistically similar to BARI Hybrid Tomato-4 and BARI Hybrid Tomato-5 but varied significantly with the other varieties. On the other hand, minimum number (3.95) of flowers per cluster was produced by BARI Tomato-14 which was statistically similar to BARI Tomato-15 but varied significantly with the other varieties (Table 2).

Table 2. Effect of variety on reproductive characters of tomato during winter season

Variety	Flower clusters plant^{-1}	Floral buds cluster^{-1}	Flowers cluster^{-1}	Fruits cluster^{-1}
BARI Tomato-2	6.24 d	6.01 bc	5.31 a	4.81 a
BARI Hybrid Tomato-4	9.58 a	6.35 ab	5.02 a	4.32 abc
BARI Hybrid Tomato-5	6.58 cd	7.00 a	5.12 a	4.55 ab
BARI Tomato-14	8.00 b	5.42 c	3.95 b	3.62 c
BARI Tomato-15	7.83 bc	5.89 bc	4.42 ab	3.95 bc
$LSD_{0.05}$	1.32	0.83	0.93	0.82
CV (%)	11.21	8.80	12.69	12.62

4.1.10 Fruits cluster^{-1}

Analysis of variance showed that the effect of variety on number of fruits per cluster varied significantly during winter season (Appendix VII). It was found that BARI Tomato-2 produced maximum fruits per cluster (4.81), which was statistically similar to BARI Hybrid Tomato-4 and BARI Hybrid Tomato-5. BARI Tomato-14 produced the minimum fruits per cluster (3.62), which was statistically similar to BARI Hybrid Tomato-4 and BARI Tomato-15 but varied significantly with other varieties (Table 2).

4.1.11 Fruit diameter

Fruit percentage at different diameter range has been presented in Table 3. The effect of variety on fruit size during winter season showed significantly variation (Appendix VI). It was found that BARI Hybrid Tomato-5 produced maximum fruits (18.66 %) having >5.5 cm diameter which was statistically similar to BARI Tomato-2 and BARI Tomato-14. On the other hand BARI Hybrid Tomato-4 produced minimum fruits (8.25 %) having the same diameter which was statistically similar to BARI Tomato-15. In terms of larger fruit production (>5.5 cm diameter), BARI Tomato-14 and BARI Tomato-15 were statistically similar.

It was found that BARI Tomato-15 produced maximum fruits (46.59 %) having 5.5-4.0 cm diameter, which was statistically similar to BARI Tomato-14 and BARI Tomato-2. BARI Hybrid Tomato-4 produced minimum fruits (29.89 %) having the 5.5-4.0 cm diameter. However, BARI Tomato-2, BARI Hybrid Tomato-5 and BARI Tomato-14 were statistically similar in terms of fruit size of 5.5-4.0 cm diameter.

It was also found that BARI Hybrid Tomato-4 produced maximum (61.85 %) small sized fruit (<4.0 cm diameter) which varied significantly with other varieties. BARI Tomato-2, BARI Hybrid Tomato-5, BARI Tomato-14 and BARI Tomato-14 showed no statistically variation in production of fruit having < 4.0 cm diameter.

Table 3. Effect of variety on fruit diameter during winter season

Variety	**Fruit percentage at different diameter range**		
	> 5.5 cm	**5.5-4.0 cm**	**< 4 cm**
BARI Tomato-2	18.57 a	40.15 ab	41.29 b
BARI Hybrid tomato-4	8.25 c	29.89 c	61.85 a
BARI Hybrid tomato-5	18.66 a	38.71 b	42.63 b
BARI Tomato 14	15.13 ab	43.90 ab	40.97 b
BARI tomato-15	12.21 bc	46.59 a	41.19 b
$LSD_{0.05}$	4.43	7.53	10.22
CV (%)	19.78	12.28	14.55

4.1.12 Total soluble solid (% TSS) content of fruit

The effect of varieties on total soluble solid content (% TSS) of fruit in winter season was varied significantly (Appendix VII). The maximum total soluble solid (5.42 %) was obtained from fruit of BARI Hybrid Tomato-5 whereas the minimum total soluble solid (4.26%) was obtained from BARI Tomato-2. The other three BARI tomato varieties *viz.*, BARI Hybrid Tomato-4, BARI Tomato-14 and BARI Tomato-15 showed no statistically similar total soluble solid (% TSS) content of fruit.

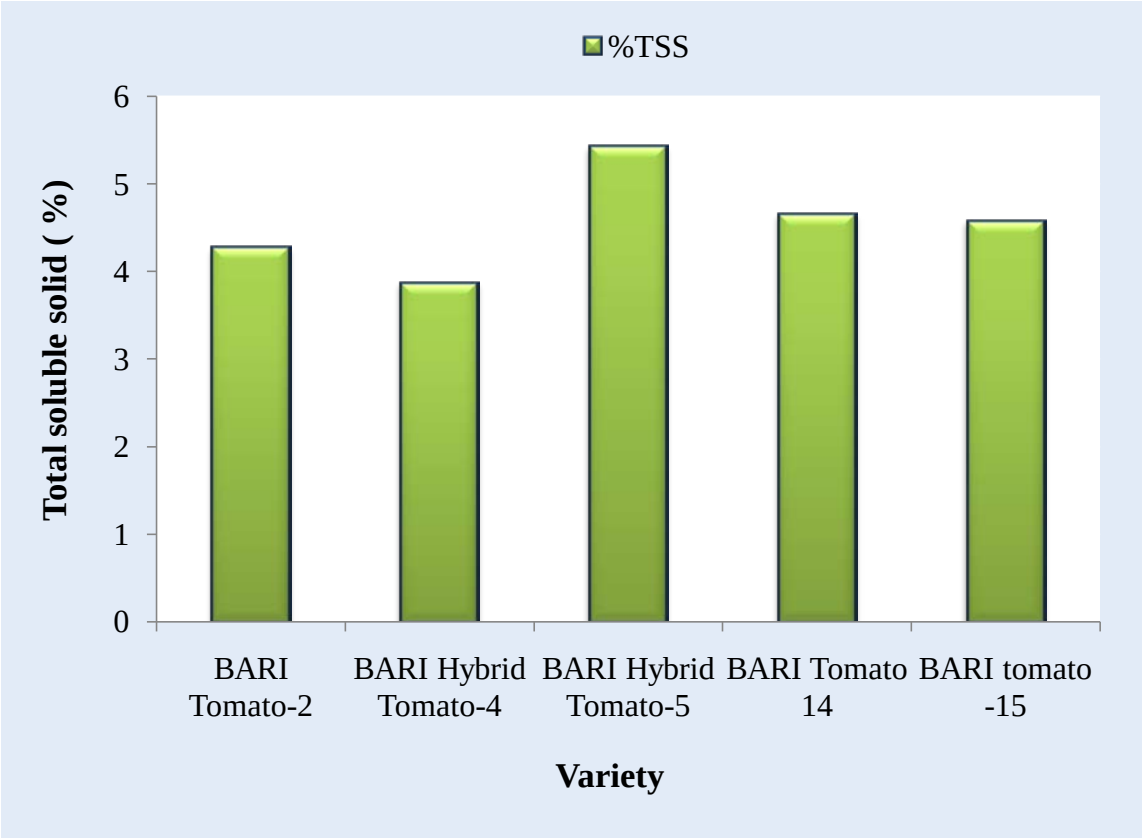

Figure 4. Effect of variety on total soluble solid percentage of fruit during winter season ($LSD_{0.05}$ =0.29)

4.1.13 Fruits plant^{-1}

Analysis of variance showed that the effect of variety on total number of fruits per plant during winter was varied significantly (Appendix VII). It was found that BARI Hybrid Tomato-4 produced maximum fruits per plant (41.33) which was statistically significant with other tomato varieties. BARI Tomato-14 produced minimum fruits pen plant (28.66), which was statistically similar to BARI Tomato-2 and BARI Hybrid Tomato-5. Total fruit per plant of BARI Tomato-2, BARI Hybrid Tomato-5 and BARI Tomato-15 was also statistically similar.

4.1.14 Average fruit weight

The effect of variety on average fruit weight showed significant variation during winter season (Appendix VII). It was found that the average fruit weight of BARI Tomato-14 was maximum (74.19 g fruit^{-1}) which was statistically significant with other tomato varieties. The minimum average fruit weight (32.69 g fruit^{-1}) was found in BARI Hybrid Tomato-4 which was statistically significant with other varieties. It was also observed that average fruit weight (66.73 g fruit^{-1}) of BARI Tomato-2 was statistically similar to average fruit weight of BARI Hybrid Homato-5.

4.1.15 Fruit weight plant^{-1}

The effect of varieties on total fruit weight per plant showed no significantly variation (Appendix VII). The maximum total fruit weight (2.09 kg plant^{-1}) was given by BARI Tomato-14 and minimum total fruit weight (1.32 kg plant^{-1}) was given by BARI Hybrid Tomato-4 (Table 4). The main cause behind this result was total number of fruit per plant and individual fruit weight. Although BARI Hybrid Tomato-4 produced maximum number of fruits (41.33 fruit plant^{-1}), but average individual fruit weight (32.69 g fruit^{-1}) was minimum. On the other hand BARI Tomato-14 produced minimum number of fruits (28.66 fruit plant^{-1}), but average individual fruit weight (74.19 g fruit^{-1}) was maximum.

Table 4. Effect of variety on yield and yield contributing characters of tomato during winter season

Variety	Fruits plant^{-1}	Average fruit weight (g)	Fruit weight plant^{-1} (kg)	Yield (t ha^{-1})
BARI Tomato-2	29.69 bc	66.73 b	1.95 a	54.23 ab
BARI Hybrid tomato-4	41.33 a	32.69 d	1.32 a	36.87 c
BARI Hybrid tomato-5	30.08 bc	67.50 b	1.98 a	55.14 ab
BARI Tomato-14	28.66 c	74.19 a	2.09 a	58.19 a
BARI Tomato-15	34.16 b	50.61 c	1.71 a	47.71 b
$LSD_{0.05}$	4.49	4.88	1.01	8.07
CV (%)	8.91	5.43	10.39	10.40

4.1.16 Yield

The yield of tomato varieties has been presented on table 4. The variation among the tomato varieties on fruit yield per hectare during winter was statistically significant (Appendix VII). It was found that BARI Tomato-14 produced maximum fruit (58.19 t ha^{-1}), which was statistically similar to BARI Tomato-2 and BARI Hybrid Tomato-5. On the other hand, BARI Hybrid Tomato-4 produced minimum fruit (36.87 t ha^{-1}) which was statistically significant with other varieties. The yield performance of BARI Tomato -2, BARI Hybrid Tomato-5 and BARI Tomato-15 was statistically similar.

4.2 SUMMER SEASON (April 20, 2014 planting)

4.2.1 Plant height at different days after transplanting

Plant height at different days after transplanting has been presented in the figure 5. Analysis of variance indicated that the effect of varieties on plant height at different days after transplanting (DAT) was varied significantly during summer season (Appendix VIII). It was found that BARI Hybrid Tomato-5 produced the tallest plant at 25 DAT (30.75 cm), which was statistically similar to BARI Tomato-2 and BARI Hybrid Tomato-4. The BARI Tomato-14 produced the shortest plant at 25 DAT (21.21 cm) which varied significantly with the other varieties.

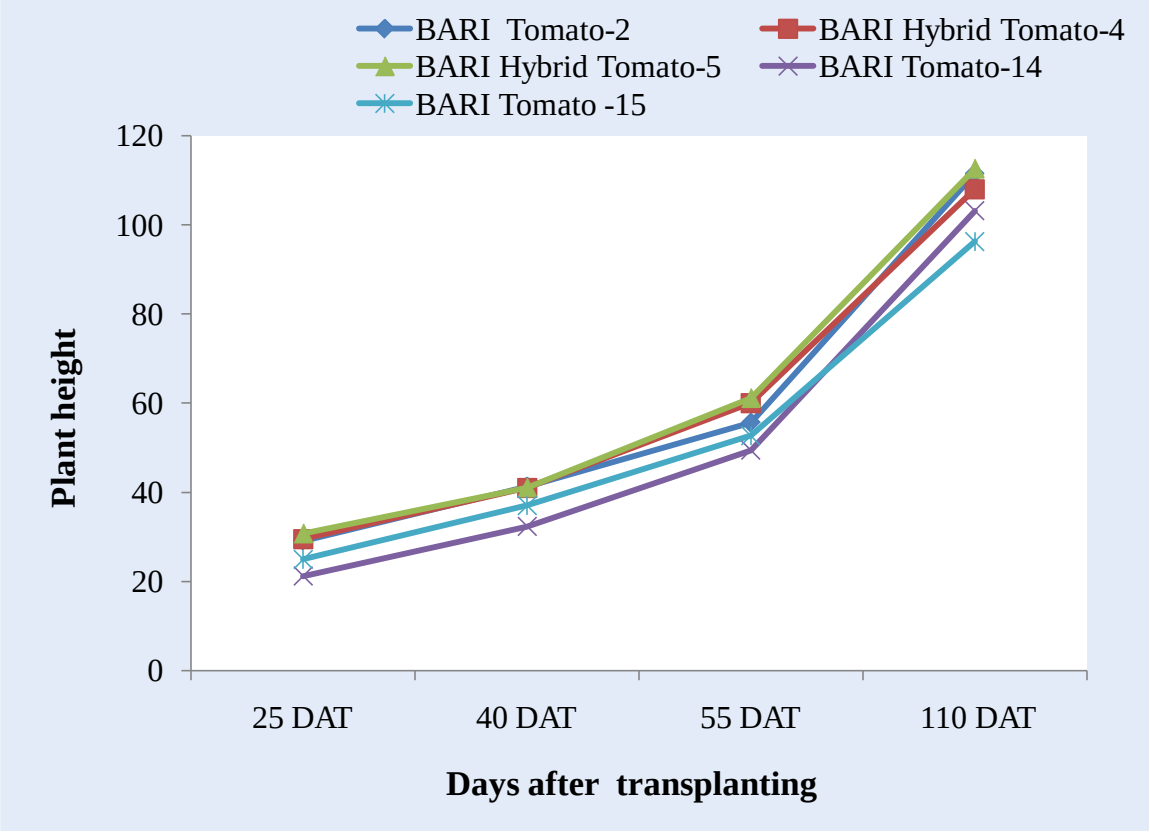

Figure 5. Effect of variety on plant height at different days after transplanting during summer season ($LSD_{0.05}$ = 2.20, 2.64, 3.70 and 4.29 at 25 DAT, 40 DAT, 55 DAT and 110 DAT respectively)

The BARI Tomato-2 produced the tallest plant (41.26 cm) at 40 DAT, which was statistically similar to BARI Hybrid Tomato-4 and BARI Hybrid Tomato-5 but varied significantly with the other varieties. The BARI Tomato-14 produced the shortest plant (32.35 cm) at 40 DAT which was statistically significant with the other varieties.

The BARI Hybrid Tomato-5 produced the tallest plant at 55 DAT (61.13 cm), which was statistically similar to BARI Hybrid Tomato-4 but varied significantly with the other varieties. The BARI Tomato-14 produced the shortest plant (49.42 cm) at 55 DAT which was statistically similar to the BARI Tomato-15 but varied significantly with the other varieties.

Analysis of variance also indicated that the effect of tomato varieties on plant height at final harvest varied significantly during summer season (Appendix VIII). It was found that BARI Hybrid Tomato-5 produced the tallest plant (112.6 cm) at 110 DAT (final harvest) which was statistically similar to BARI Tomato-2 but varied significantly with the other varieties. The BARI Tomato-15 produced shortest plant (96.30 cm) at final harvest which was statistically significant with the other varieties.

From the results of plant height at different days after transplanting during winter and summer season, it was clear that growth rate of tomato during summer season (Fig. 5) was slightly higher than winter season (Fig. 1). There might be some causes for such an increased growth rate during summer. Exact fact was not examined but vegetative growth potentiality of tomato at high temperature, availability of soil nutrient at higher soil temperature, effect of partial shading, higher level of activity of growth substances, alteration of enzyme activities etc**.** might be the main causes. An accelerated stem and leaf elongation, suppressed branching, an increase in specific leaf area (SLA) and a decrease in allocation to root mass under partial shade condition was reported by Ballare´ *et al.* (1991);

Sultan (2000) which support the of synergistic effect of poly-tunnel shade on plant height of tomato of the experiment (4.2) .The similar results were evident in the study of Thangam and Thamburaj (2008). They observed that plants grown under shade exhibited better growth in terms of plant height as compared to those in open field. Similarly Paez and Lopez (2000) observed that plant height and leaf area increased in the shade. Murakami *et al*. (1997) stated that red light interception caused low ratio of red and far red light, which resulted in increase in plant height.

4.2.2 Root dry weight

Analysis of variance showed that the effect of tomato varieties on root dry matter accumulation per plant at final harvest was statistically significantly during summer season (Appendix IX). The maximum (2.06 g plant^{-1}) root dry matter accumulation was found in BARI Hybrid Tomato-5 which was statistically similar to BARI Tomato-2, BARI Hybrid Tomato-4, BARI Tomato-14 and BARI Tomato-15. The minimum (1.45 g plant^{-1}) root dry matter accumulation was found in BARI Hybrid tomato-4 which varied significantly with the other varieties (Table 5).

4.2.3 Shoot dry weight

The variation in shoot dry matter accumulation per plant at final harvest due to the varietal effect of tomato was statistically significant during summer season (Appendix IX). The highest (22.53 g plant^{-1}) shoot dry matter accumulation was found in BARI Hybrid Tomato-5 which varied significantly with the other varieties (Table 5). The lowest (11.80 g plant^{-1}) shoot dry matter accumulation was found in BARI Tomato-14 which was statistically similar to BARI Tomato-15 but varied significantly with the other varieties.

4.2.4 Total vegetative dry matter weight

Analysis of variance showed that the effect of tomato varieties on total vegetative dry matter accumulation per plant at final harvest was varied significantly during summer season (Appendix IX). The highest total vegetative dry matter (24.59 g plant^{-1}) accumulation was found in BARI Hybrid Tomato-5 which was statistically significant with the other varieties. The lowest total vegetative dry matter (13.59 g plant^{-1}) accumulation was found in BARI Tomato-14 which was statistically similar to the BARI Hybrid Tomato-15 but varied significantly to the other tomato varieties (Table 5).

From the result of statistical analysis of total dry matter accumulation per plant, it was found that relative development of plant system of five BARI Tomato varieties varied significantly as influenced by variety. As like plant height, accumulation of root and shoot dry matter, the total dry matter accumulation per plant of BARI Hybrid Tomato-5 was also better in comparison with other four BARI tomato varieties.

Starting from the late reproductive phase, fruit setting to fruit development and subsequent maturation a large part of photosynthate accumulates into the sink, the developing fruits. But during the summer season, a complete failure of reproduction by all the five tomato was observed. Although fruit setting was occurred in, BARI Hybrid Tomato-4 and BARI Hybrid Tomato-5 but all the fruits dropped prematurely. These could be the cause, why all the five-tomato varieties showed relatively higher amount of dry matter accumulation in plant body systems during summer season (Table 5) in comparison with winter season (Table 1).

Table 5: Effect of variety on dry matter accumulation in different plant parts during summer season

Variety	Root dry weight plant^{-1} (g)	Shoot dry weight plant^{-1} (g)	Total vegetative dry weight plant^{-1} (g)
BARI Tomato-2	1.89 b	19.61 b	21.50 b
BARI Hybrid Tomato-4	1.45 d	14.78 c	16.23 c
BARI Hybrid Tomato-5	2.06 a	22.53 a	24.59 a
BARI Tomato-14	1.79 b	11.80 d	13.59 d
BARI Tomato -15	1.64 c	12.07 d	13.72 d
$LSD_{0.05}$	0.13	1.86	1.92
CV (%)	4.92	7.48	6.98

4.2.5 SPAD value of leaf

SPAD meter reading of leaf was analyzed and presented in order to having an idea about relative leaf chlorophyll content per unit leaf area of the tomato varieties. Analysis of variance indicated that the effect of tomato varieties on relative chlorophyll content of leaf was varied significantly during summer season (Appendix IX). The maximum SPAD value (42.20) was recorded in leaf of BARI Hybrid Tomato-5 which was statistically similar to BARI Tomato-2, BARI Hybrid Tomato-4 and BARI Tomato-14. The minimum SPAD value (37.83) was recorded in leaf of BARI Tomato-15 which was statistically similar to BARI Hybrid Tomato-4 but varied significantly with the other varieties.

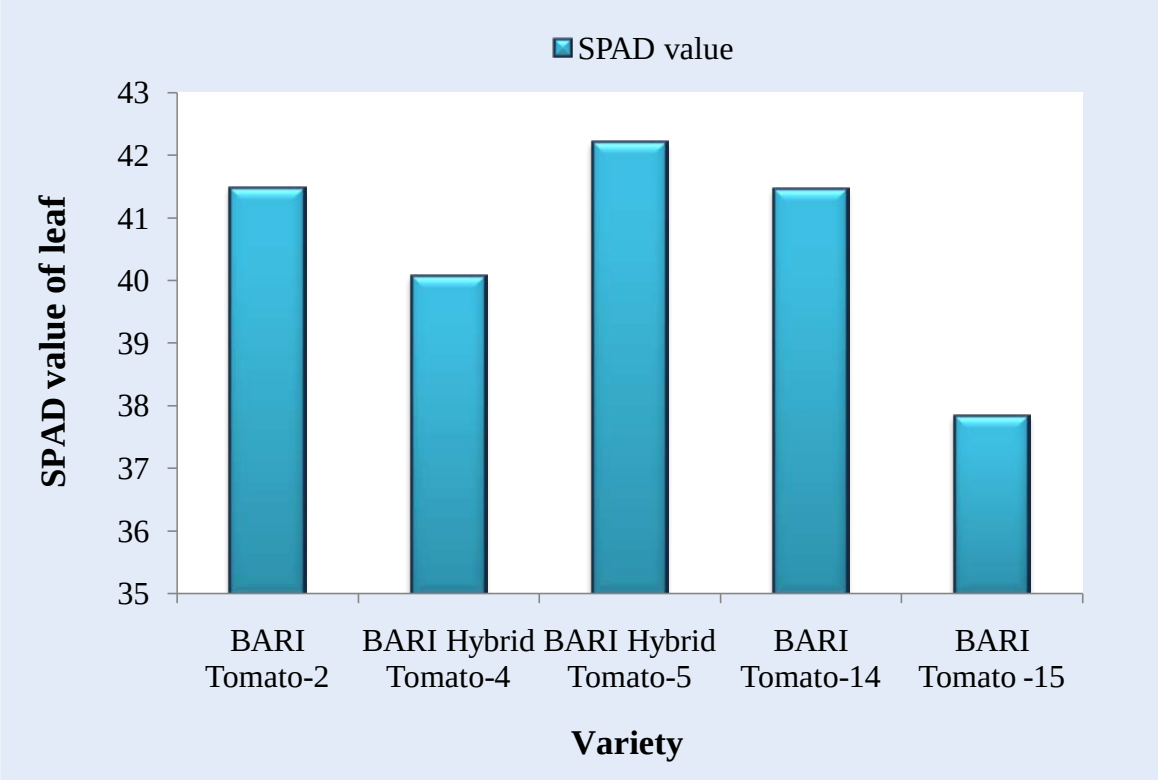

Figure 6. Effect of variety on relative chlorophyll content of leaf during winter season ($LSD_{0.05}$ = 2.28)

4.2.6 Days to first appearance of inflorescence

Time required to the first appearance of inflorescence has been presented by figure 7. Analysis of variance indicated that the effect of tomato varieties on days from transplanting to first appearance of inflorescence was varied significantly during summer season (Appendix X). It was found that BARI Tomato-2 required maximum time (27.58 days) for the first appearance of inflorescence, which was statistically similar to BARI Hybrid Tomato-5. The minimum time (22.67 days) for first inflorescence initiation was required by BARI Tomato-14, which was statistically similar to BARI Hybrid Tomato-4 BARI Tomato-15 but varied significantly with other varieties.

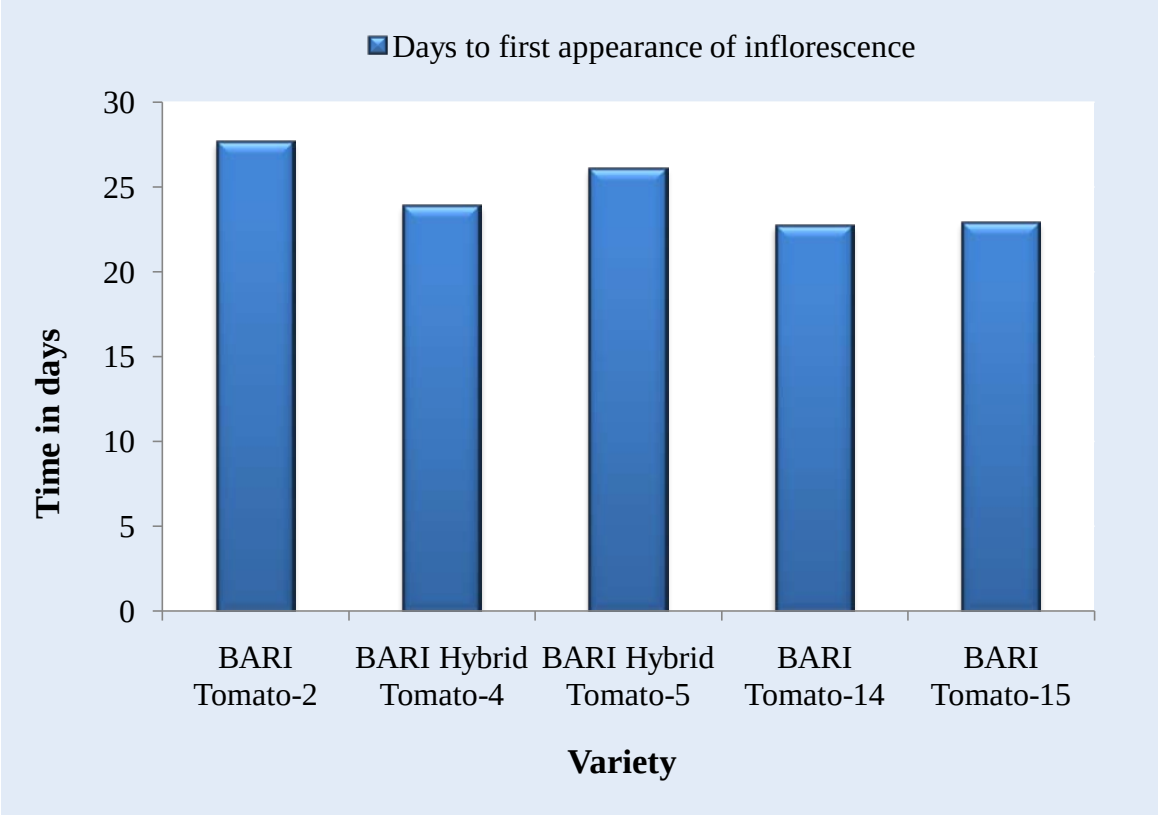

Figure 7. Effect of variety on first appearance of inflorescence during winter season ($LSD_{0.05}$ = 1.79)

4.2.7 Clusters plant^{-1}

Analysis of variance indicated that the effect of varieties on cluster number per plant was varied significantly during summer season (Appendix X). Result found that the maximum flower clusters per plant (8.16) was produced by BARI Hybrid Tomato-5 which was statistically similar to BARI Hybrid Tomato-4. On the other hand minimum flower clusters per plant (4.41) was produced by BARI Tomato-14 which varied significantly with the other tomato varieties (Table 6).

4.2.8 Floral buds cluster^{-1}

Analysis of variance indicated that the effect of varieties on number of floral buds per cluster was varied significantly during summer season (Appendix X). It was found that BARI Hybrid Tomato-5 produced maximum floral buds per cluster (6.77), which was statistically similar to BARI Tomato-2, BARI Hybrid Tomato-4 and BARI Tomato-15. The minimum floral buds per cluster (5.30) was produced by BARI Tomato-14 which was statistically similar to BARI Tomato-2 and BARI Tomato-15 but varied significantly with the other varieties (Table 6).

4.2.9 Flower cluster^{-1}

The effect of varieties on number of flowers per cluster was varied significantly during summer season (Appendix X). It was found the BARI Hybrid Tomato-4 produced maximum flowers per cluster (4.71) which was statistically similar to BARI Hybrid Tomato-5 but varied significantly with the other varieties. On the other hand, BARI Tomato-2 produced minimum flowers per cluster (1.66) which was statistically significantly to the other varieties. The flowers per cluster produced by BARI Tomato-14 and BARI Tomato-15 were statistically similar (Table 6).

Table 6. Effect of variety on reproductive characters of tomato during summer season

Variety	Clusters plant^{-1}	Floral buds cluster^{-1}	Flower cluster^{-1}
BARI Tomato-2	6.33 c	5.89 ab	1.66 c
BARI Hybrid Tomato-4	7.75 ab	6.37 a	4.71 a
BARI Hybrid Tomato-5	8.16 a	6.77 a	4.68 a
BARI Tomato-14	4.41 d	5.30 b	3.32 b
BARI Tomato-15	6.75 bc	6.33 ab	3.69 b
$LSD_{0.05}$	1.21	1.03	0.57
CV (%)	11.76	10.91	10.34

In case of number of flowers per cluster, three high yielding BARI tomato varieties *viz.*, BARI Tomato-2, BARI Tomato-14 and BARI Tomato-15 showed high degree of variation of floral bud to flower development compare to BARI hybrid varieties *viz.*, BARI Hybrid Tomato-4 and BARI Hybrid Tomato-5. The highest degree of variation on number of floral buds per cluster to flowers per cluster was found in BARI Tomato-2 (Table 6). The number of flowers per clusters was lowest in BARI Tomato-2 which was due to the least development of clusters and most of the floral buds dried up before flower blossom and/or complete died up of entire cluster with vestigial floral buds. This result indicated that there might be a number of physiological abnormalities aroused inside the plant body at high temperature (>30^{o}C) which possibly caused rapid buildup of growth retardant (ethylene and/or abscissic acid) that ultimately abscised floral bud or the entire clusters as well.

4.2.10 Fruits cluster^{-1}

The inbred BARI tomato varieties *viz.*, BARI Tomato-2, BARI Tomato-14 and BARI Tomato-15 showed complete absence of fruit setting during summer season but fruit setting was found in hybrid varieties *viz.*, BARI Hybrid Tomato-4 and BARI Hybrid Tomato-5. Although fruit setting was observed in Hybrid Tomato varieties during summer season, all the fruits dropped prematurely when they attained approximate a centimeter diameter. The interpretation of data regarding fruits per cluster to was excluded for avoiding unnecessary complexity.

CHAPTER V

SUMMARY AND CONCLUSION

The research was comprised of two pot experiments conducted at the research farm of Sher-e-Bangla Agricultural University (SAU) during two consecutive growing seasons, viz., winter (*Rabi*) and summer (*Kharif-1*) of 2013-2014. The treatments of both the experiments were five selected BARI tomato varieties, namely, BARI Tomato-2, BARI Hybrid Tomato-4, BARI Hybrid Tomato-5, BARI Tomato-14 and BARI Tommto-15. They were planted on November 20, 2013 and April 20, 2014 during winter and summer seasons respectively. The experiments were laid out in Randomized Complete Block Design (RCBD) having one factor with four replications.

Data were taken on growth, yield contributing characters and yield in order to study morpho-physiological as well as yield attributes of the selected tomato varieties during two different growing seasons. The data were statistically analyzed using MSTAT-C statistical analysis software for evaluation. The summary of the results has been presented in this chapter.

The effect of variety was found to be significant in almost all parameters during winter season. The tallest plant at different days after transplanting (31.26 cm, 39.96 cm, and 54.48 cm at 25 DAT, 40 DAT and 55 DAT respectively), was produced by BARI Hybrid Tomato-5. This variety also produced the tallest plant at final harvest (109.70 cm) which was, however, statistically similar to BARI Tomato-2. Significant variation in dry matter accumulation in plant parts at final harvest was observed. The maximum root dry mass (1.82 g plant^{-1}) was found in BARI Hybrid Tomato-5 but maximum shoot dry mass (17.52 g plant^{-1}) and total vegetative dry mass (19.10 g plant^{-1}) were found in BARI Tomato-2. Root, shoot and total vegetative dry mass accumulation of BARI Tomato-2 and BARI Hybrid Tomato-5 were statistically similar. Hybrid Tomato-15 gave statistically the lowest values of dry mass accumulation on different plant parts. Relative chlorophyll content per unit leaf

area based on SPAD value was significantly varied and maximum SPAD value (46.20) was obtained in leaf of BARI Hybrid Tomato-5. The minimum days from transplanting to appearance of first inflorescence was required by BARI Tomato-14. Significant variation in number of clusters per plant, number of floral buds per cluster, number of flowers per cluster, number of fruits per clusters was observed due to varietal influence during winter season. BARI Hybrid Tomato-4 produced the maximum number of clusters per plant (9.58), whereas BARI Hybrid Tomato-5 produced maximum number of floral buds per cluster (7.00), which was statistically similar to the former one. The maximum number of flowers per cluster (5.31) was produced by BARI Tomato-2, which showed no significant variation with BARI Hybrid Tomato-4 and BARI Hybrid Tomato-5. BARI Tomato-2 produced maximum fruits per cluster (4.83), which was statistically similar to BARI Hybrid Tomato-4 as well as BARI Hybrid Tomato-5. BARI Hybrid Tomato-4 produced maximum number of fruits per plant (41.33 fruit plant^{-1}). The fruit size was significantly influenced by variety. BARI Hybrid Tomato-5 produced the highest number (18.66 %) of large sized fruit (>5.5 cm diameter) during winter which was statistically similar to that of BARI Tomato-2 and BARI Tomato-14. BARI Hybrid Tomato-4 produced the maximum number (61.85%) of small sized fruits (<4.0 cm diameter). It was observed that average fruit weight of BARI Tomato-14 was significantly higher (74.19 g fruit^{-1}) than other varieties but significantly higher total soluble solid (5.42 %) was obtained in BARI hybrid Tomato-5.The effect of varieties on total fruit weight per plant showed no significant variation, but maximum fruit (2.09 kg plant^{-1}) was produced by BARI Tomato-14. BARI Tomato-14 gave maximum fruit yield (58.19 t ha^{-1}), which was statistically similar to that of BARI Tomato-2 and BARI Hybrid Tomato-5.

During the summer season, the variation among the tomato varieties was found to be significant in almost all vegetative and early reproductive characters. The tallest plants, 30.75 cm, 41.07 cm, 61.13 cm and 112.60 cm at 25 DAT, 40 DAT, 55 DAT and 110 DAT (final harvest) were produced by BARI Hybrid Tomato-5. Plant heights of BARI Tomato-2 and BARI Hybrid Tomato-5 were

statistically similar at different days after transplanting. The highest root dry mass (2.06 g plant^{-1}), shoot dry mass (22.53 g plant^{-1}) as well as total vegetative dry mass (24.59 g plant^{-1}) were found in BARI Hybrid Tomato-5 during summer season. All tomato varieties except BARI Toamto-15 gave statistically similar SPAD value of leaves. The minimum time (22.67 days) from transplanting to first appearance of inflorescence was observed in BARI Tomato-14 during summer which was statistically similar to BARI hybrid Tomato-4 and BARI Tomato-15 during the same season. BARI Hybrid Tomato-5 produced maximum (8.16) clusters per plant, during summer which was statistically similar to BARI Hybrid Tomato-4. BARI Hybrid Tomato-5 produced maximum (6.78) floral buds per cluster during summer season which was statistically similar to that of BARI Tomato-2, BARI Hybrid Tomato-4 and BARI Tomato-15. BARI Hybrid Tomato-4 produced the maximum (4.71) flowers per cluster which was statistically similar to BARI Hybrid Tomato-4 and BARI Hybrid Tomato-5.

BARI Tomato-2 showed extreme severity of cluster production under summer condition, which produced mostly rudimentary or least developed cluster that is why minimum number of flowers per cluster (1.66) was obtained. On the other hand, BARI Tomato-14 produced very few flower clusters per plant during the summer (April 20, 2014 planting) season. During summer season, a complete failure of yield was observed. All the BARI Tomato varieties except BARI Hybrid Tomato-4 and BARI Hybrid Tomato-5 were failed to set fruit during the summer season.

Conclusion and recommendations

Based on the findings of the present study, it may be concluded that variety have remarkable influence on morpho-physiology and yield attributes of tomato. BARI Tomato-2, BARI Hybrid Tomato-5 and BARI Tomato-14 planted on winter (November 20) season would be beneficial at farmers' level but BARI Tomato -14 would be better when quality is concern. The varietal effects suggest that specific variety having resistant to heat stress should be planted during summer season. In order to prevent fruit dropping, BARI Hybrid Tomato-4 can be cultivated with application of PGRs during summer season. Overall performance of BARI Hybrid Tomato-5 indicates that it can be an excellent working material for researchers who are involved in the varietal development of tomato especially suitable for summer season.

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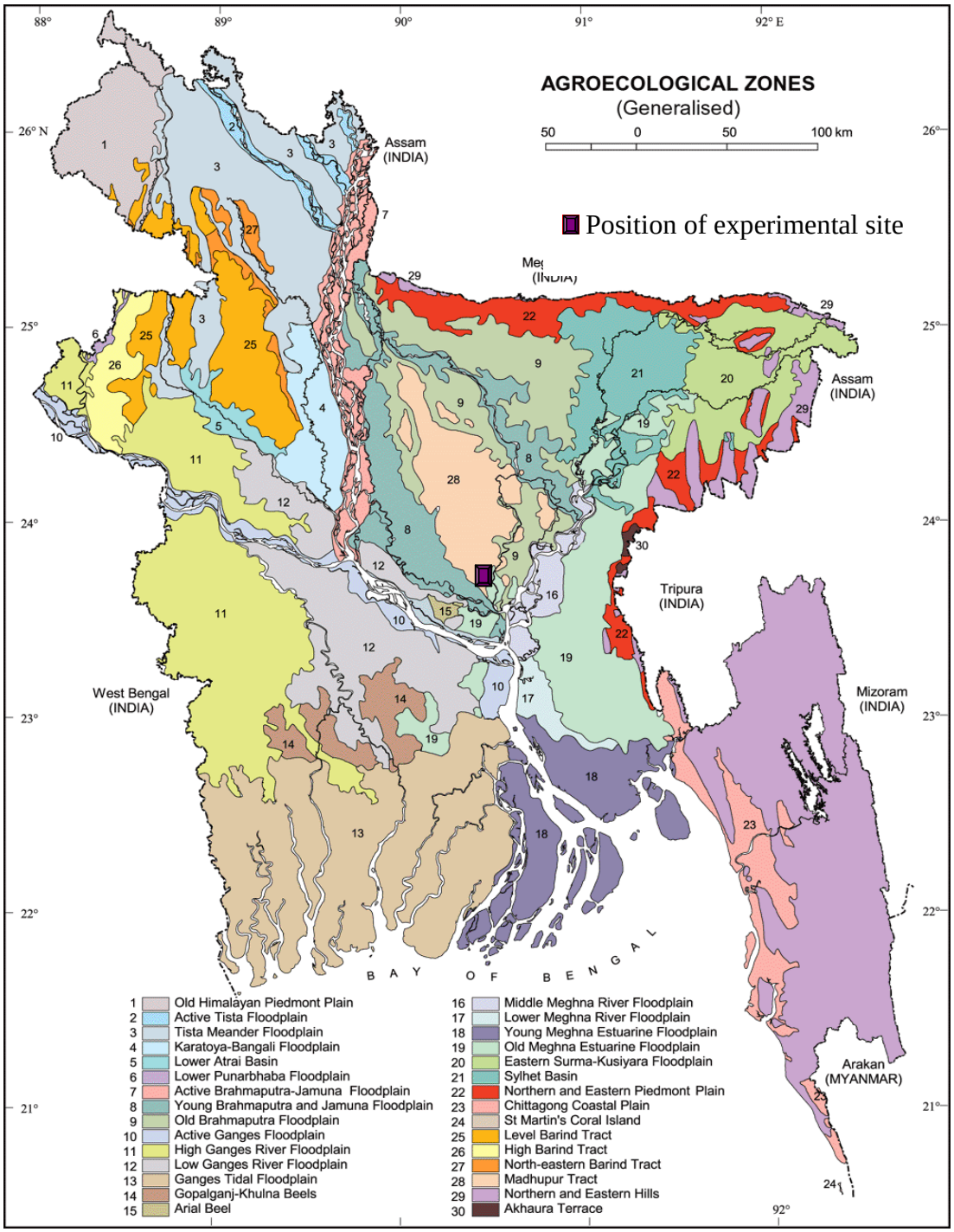
APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. Weather of Dhaka: Monthly average minimum and maximum temperature, precipitation and relative humidity

Year	Month	Average air temperature (^{0}C)		Average precipitation (mm)	Average Relative humidity (%)
		Maximum	Minimum		
2013	October	30.8	14.85	44.64	67.82
	November	28.1	6.88	15.6	58.18
	December	25.36	6.12	0.62	54.3
2014	January	25	12	18	46
	February	28	13	31	37
	March	33	16	58	38
	April	35	23	103	42
	May	33	23.22	134	57.44
	June	32	24	269	72.36
	July	31	24	296	79
	August	31	24.72	245	78

Source: SAU weather station, SAU, Dhaka

Appendix III. Analysis of variance of the data on plant height at different dads after transplanting (DAT), and at final harvest (110 DAT) during winter season

Source of variation	Degree of freedom	Mean square			
		Plant height (cm) at different days after transplanting(DAT)			
		25 DAT	40 DAT	55 DAT	110 DAT (Final harvest)
Replication	3	1.26	1.40	10.02	18.49
Treatment (variety)	4	91.85**	85.53**	132.52**	233.95**
Error	12	2.56	3.97	5.05	9.76

** Significant at 1% level of probability

Appendix IV. Analysis of variance of the data on SPAD value of leaf and dry weight of plant parts during winter season

Source of variation	Degree of freedom	Mean square			
		SPAD value of leaf	Root dry weight plant^{-1} (g)	Shoot dry weight plant^{-1} (g)	Total vegetative dry weight plant^{-1} (g)
Replication	3	0.50	0.004	0.98	0.97
Treatment(variety)	4	20.15*	0.19**	52.10**	54.60**
Error	12	5.91	0.04	2.53	2.96

** Significant at 1% level of probability, *significant at 5% level of probability

Appendix V. Analysis of variance of the data on days to first appearance of inflorescence, flower clusters per plant, floral buds per cluster and flowers per cluster of tomato during winter season

Source of variation	Degree of freedom	Mean square			
		Days to first appearance of inflorescence	Flower clusters plant^{-1}	Floral buds cluster^{-1}	Flowers cluster^{-1}
Replication	3	0.53	0.52	0.17	0.06
Treatment (variety)	4	33.92**	7.00**	1.38**	1.26*
Error	12	2.49	0.73	0.29	0.36

** Significant at 1% level of probability, *significant at 5% level of probability

Appendix VI. Analysis of variance of the data on percent fruit size at different diameter range and total soluble solid content of fruit of tomato during winter season

Source of variation	Degree of freedom	Mean square			
		Percent fruit size at different diameter range			Total soluble solid of fruit (% TSS)
		>5.5 cm	5.5-4.0 cm	<4.0 cm	
Replication	3	10.09	13.74	39.19	0.02
Treatment (variety)	4	78.38**	162.45**	332.38**	1.31**
Error	12	8.30	23.93	44.01	0.03

** Significant at 1% level of probability, *significant at 5% level of probability

Appendix VII. Analysis of variance of the data on yield and yield contributing characters of tomato during winter season

Source of variation	Degree of freedom	Mean square				
		Fruits cluster^{-1}	Fruits plant^{-1}	Average fruit weight (g)	Fruit weight plant^{-1} (kg)	Yield (t ha^{-1})
Replication	3	0.32	27.21	20.75	0.04	34.51
Treatment (variety)	4	0.89*	108.75**	1122.94**	0.37**	288.04**
Error	12	0.28	8.52	10.05	0.03	27.48

** Significant at 1% level of probability, *significant at 5% level of probability

Appendix VIII. Analysis of variance of the data on plant height at different dads after transplanting (DAT), and at final harvest (110 DAT) of tomato during summer season

Source of variation	Degree of freedom	Mean square			
		Plant height (cm) at different days after transplanting(DAT)			
		25 DAT	40 DAT	55 DAT	110 DAT (Final harvest)
Replication	3	0.42	2.26	7.63	8.70
Treatment (variety)	4	62.17**	60.49**	96.10**	179.22**
Error	12	2.04	2.95	5.79	7.77

** Significant at 1% level of probability

Appendix IX. Analysis of variance of the data on SPAD value of leaf and dry weight of plant parts during summer season

Source of variation	Degree of freedom	Mean square			
		SPAD value of leaf	Root dry weight plant^{-1} (g)	Shoot dry weight plant^{-1} (g)	Total vegetative dry weight plant^{-1} (g)
Replication	3	1.01	0.006	1.23	1.35
Treatment (variety)	4	12.02**	0.21**	90.05**	96.52**
Error	12	2.19	0.008	1.46	1.56

** Significant at 1% level of probability

Appendix X. Analysis of variance of the data on days to first appearance of inflorescence, flower clusters per plant, floral buds per cluster and flowers per cluster during summer season

Source of variation	Degree of freedom	Mean square			
		Days to first appearance of inflorescence	Flower cluster plant^{-1}	Floral buds cluster^{-1}	Flower cluster^{-1}
Replication	3	2.15	0.90	0.10	0.08
Treatment (variety)	4	18.32**	8.60**	1.25*	6.24**
Error	12	1.36	0.61	0.44	0.14

** Significant at 1% level of probability, *significant at 5% level of probability