MORPHO-PHYSIOLOGICAL STUDY OF TWENTY TWO SUMMER TOMATO GERMPLASM UNDER POLYSHED CONDITION

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CERTIFICATE

This is to certify that the thesis entitled **“MORPHO-PHYSIOLOGICAL STUDY OF TWENTY TWO SUMMER TOMATO GERMPLASM UNDER POLYSHED CONDITION”** submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) in HORTICULTURE,** embodies the results of a piece of bona fide research work carried out by **KHONDAKER ATIQUL ISLAM,** Registration. No. **15-06876** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

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

Dated: June, 2015

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ABSTRACT

An experiment was conducted at Horticulture Farm, Sher-e-Bangla Agricultural University during the period from May to August 2015 (kharif season) to study the morpho-physiological characteristics of different summer tomato germplasm under polyshed condition using Randomized Complete Block Design with three replications. The experimental treatment consisted of 22 germplasm that G_1-G_3 (Check), G_9 (Check), G_4-G_8 and G_{10}-G_{22}. Yield and yield contributing parameters of different tomato germplasm were compared in this study. The highest plant height (191.2 cm) was found from G_{13} (JP-27) and maximum chlorophyll content of leaves (73.2 %) was measured from G_{12} (JP-26) which was statistically similar with G_5 (AVTO-1007) (71.9 %). Days required for flowering (31.3 days) was observed from G_7 (AVTO-1002). G_{17} (Apple Netherlands) gave the longest fruit (43.1 cm) and maximum fruit diameter (13.5 cm) was found from G_{11} (JP-13). The maximum number of leaves plant^{-1} (60.2), branches plant^{-1} (26.0), flowers plant^{-1} (64.0) and fruits plant^{-1} (40.0) was recorded from G_4 (AVTO-09809). The maximum weight of single fruit (100.7 g), yield plant^{-1} (4.67 kg) and yield ha^{-1} (35.73 ton) were also recorded from G_4. Shortest period (19.3 days) was required for flowering of G_{18} (SAU san-001) and minimum fruit diameter (5.2 cm) was observed of G_2 (BINA tomato 2). The lowest chlorophyll content in leaves (31.4 %), fruit length (21.4 cm) and single fruit weight (21.3 g) were recorded from the germplasm of G_{13} Germplasm. G_{20} (Purple-4) gave the lowest fruits plant^{-1} (5.3), yield plant^{-1} (0.64 kg) and yield ha^{-1} (25.57 ton). Germplasm G_4 (AVTO-09809) was found to be the best for summer tomato production among the germplasm.

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CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum*) is a well-known plant that belongs to the family Solanaceae. It is one of the most important and popular vegetable crops of different countries of the world including Bangladesh. It is a vegetable widely consumed as either fresh or industrially processed state. The production, processing industry and trade of this crop represent businesses worth billions of dollars and provide employment for a huge number of people (De Vriend, 2011). Tomatoes are grown in Bangladesh during its winter months. The total production of tomato in Bangladesh was about 255000 tons from 25495.2 hectares of land with an average yield of 10.08 t ha^{-1} (BBS, 2014) which is very low as compared to the other tomato producing countries. As improvement of the tomato crop would enhance agricultural productivity and facilitate food security. However, most of the germplasm in the country is largely undocumented and have unknown morphological, agronomic and biochemical attributes. Tomato, the world’s largest grown vegetable crop known as a protective food occupies an important place in the economy of human societies because of its high nutritive value and its wide spread production in different agroclimatic conditions. It is often called poor man’s orange, because of its high nutritive value. Keeping in view the nutritional importance of this crop, there is a need for breeding programmes in order to develop cultivars with high quality of fruit as well as yield. Identification of superior genotypes, therefore, becomes imperative to build up gene pool, which can be directly utilized in commercial cultivation and production of promising hybrids. It is cultivated in almost all home gardens and also in the field due to it's adaptability to wide range of soil and climate (Ahmed, 1976). Tomato is very rich in nutrients, especially potassium, folic acid, vitamin C and contains a mixture of different carotenoids, including vitamin A, effective β-carotene as well as lycopene (Wilcox *et al.* 2003). It contains calories 97, iron 2.7 mg, protein 4.5 g, riboflavin 0.15 mg, calcium 50 mg, niacin 3.2 mg, phosphorus 123 mg and ascorbic acid 102 mg per pound edible portion (Lester, 2006). Lycopene one of nature's most powerful antioxidant, is present in tomatoes and especially when tomatoes are cooked, had been found beneficial in preventing prostrate cancer. The consumption of tomatoes rich in lycopene leads directly to a decreased incidence of cancer in mouth, pharynx, esophagus, stomach, large intestine and rectum (Franceschi *et al.* 1994). Americans use the fresh fruit orally for kidney and liver problems, as a cathartic and to keep good digestion. There are many different types of tomato varieties in the world. Farmers in our country will now be able to cultivate tomatoes even in summer following the successful harvest of some new varieties in different district recently because potentiality to grow in summer also. The production of tomato in summer is limited due to the type of weather prevails in the summer season of Bangladesh (Ahmad, 2002). During this period, the temperature (both day and night), humidity, rainfall and light intensity which are actually the basic limiting factors of tomato production in the tropics, remain very high (Abdulla and Verkert, 1968). So, year round tomato production in Bangladesh is constrained. Attempts have been made to develop heat-tolerant varieties in some countries. There are two major problems in raising summer tomatoes in Bangladesh: first, the lack of technique to grow tomatoes under hot and rainy conditions; and second, the lack of suitable varieties which can set fruit under higher temperature. Maximum day and minimum night temperature above 32^0C and 21^0C respectively are known to limit fruit set due to an impaired physiological process in flowering and fruiting or abscission (Bhattarai and Subedi, 1996). Fruit setting in tomato is reportedly interrupted at temperature above 26^0C and 20^0C in day and night respectively and often completely arrested above the temperature 38^0C and 27^0C in day and night respectively (Stevens and Rudich, 1978). So, by producing tomato in summer season of Bangladesh, it is possible to produce tomato throughout the year and thereby to meet our demand. Considering the above facts, the present study was undertaken to evaluate the morpho-physiological study of 22 summer tomato germplasm under polyshed condition for cultivation in summer with a view to identify the potential variety of summer tomato for Bangladesh. Tomato is a mainly winter vegetable in Bangladesh. The production of tomato in summer is limited because of high temperature, heavy rainfall and severe infestation of diseases. Temperature plays a major role in phenological development and productivity of crop plants. High temperature influences crops to mature earlier (Awal *et al*., 2003). Tomato plant grown under polyhouse was observed to be earlier in flowering and fruit setting by about 3 and 8 days, respectively when compared to the crop raised under open condition (Ganesan, 2002b).

Therefore, the polyhouse environment may provide a new scope for commercial production of high value vegetable crops like tomato. It has been in use for vegetable production with far better yield in more than fifty countries all over the world (Kanthaswamy *et al*., 2000; Ganesan, 2002a, b, c; Srivastava *et al*., 2002; ICAR, 2005; Aberkain *et al*., 2006). However, the feasibility of this technology and its effect on tomato production is not well known in Bangladesh condition. Therefore, it is essential to explore the growth, development and yield of tomato crop grown under simple, environmentally friendly and lost cost polyhouse which can be used by the small and marginal farmers of the country.

So, by producing tomato in summer season of Bangladesh, it is possible to produce tomato throughout the year and thereby to meet our demand.

Considering the above facts, the present study was undertaken to evaluate the morpho-physiological study of twenty two summer tomato germplasm under polyshed condition with a view to characterise and identify the potential germplasm of summer tomato for Bangladesh.

With these circumstances, the present study was undertaken to characterize the suitable germplasm for summer tomato production in Bangladesh.

CHAPTER II

REVIEW OF LITERATURE

Tomato (*Solanum lycopersicum*) is a popular vegetable crop in both tropical and temperate regions. It is relatively cool temperature loving crop, hence grown in temperate countries and in the dry winter months of tropical countries. The crop is extremely sensitive to hot and wet growing conditions. In no part of the world much effort has been given to develop varieties adaptable to the tropics other than winter months. In Bangladesh such effort is even meager. Therefore, information available regarding tolerance to high temperature stress in tomato are reviewed and presented in this section.

Maiti *et al.* (2014) observed 100 genotypes of tomato grown in polyhouse during summer for general morphological and anatomical characters of leaves of one hundred tomato genotypes and its possible relation with drought and heat stress tolerance and resistance to insects probably tospo virus resistance. There existed a lot of variability of leaf morphology and its anatomy. It is concluded that lines having thick leaves and medium to high density of trichomes, minimum wilting, high number of flowers, may be considered for heat stress and drought tolerance. Lines with high density of trichomes are probably tospovirus resistance which could be confirmed in rainy season in the field. Genotypes with open canopy, thick petiole and thick leaves expected to be drought resistance. Anatomically compact long palisade tissue and more number of collenchyma layers in petioles offer drought resistance. Five genotypes were selected for good pollen viability. More than thirty genotypes possessed high trichome density which may be expected for TLC and Tospo virus resistance. These lines may be evaluated for TLC and Tospo virus resistance at hotspots. These lines are also expected to be tolerant to drought.

Parvej *et al.* (2010) conducted an experiment in a covered polyhouse along with an open field (control) to compare the phenological development and production potentials of two tomato varieties viz. BARI Tomato-3 and Ratan under polyhouse and open field conditions. Photosynthetically active radiation inside the polyhouse was reduced by about 40% compared to the outside (i.e. open field) while air and soil temperatures were always remained higher. From December to February the mid day air temperature under polyhouse and open field varied from 31.8 to 39.1ºC and 23.3 to 31.1ºC, respectively indicating about 8ºC higher air temperature inside polyhouse and during that time the average air temperature inside polyhouse was about 28ºC which was optimum for the growth and development of tomato plants. Relative humidity had opposite trends with that of air temperature i.e. it was lower inside the polyhouse as compared to open field. The above microclimatic variabilities inside polyhouse favoured the growth and development of tomato plant through increased plant height, number of branches/plant, rate of leaf area expansion and leaf area index over the plants grown in open field. Flowering, fruit setting and fruit maturity in polyhouse plants were advanced by about 3, 4 and 5 days, respectively compared to the crop raised in open field condition. Polyhoused plants had higher number of flower clusters/plant, flowers/cluster, flowers/plant, fruit clusters/plant, fruits/cluster and fruits/plant, and fruit length, fruit diameter, individual fruit weight, fruit weight/plant and fruit yield over open field condition. The fruit yield obtained from the polyhouse was 81 t/ha against 57 t/ha from the open field.

Mehraj *et al.* (2014) conducted an experiment at Horticultural farm of Sher-e-Bangla Agricultural University, Bangladesh for performance evaluation of twenty tomato cultivar coded from V_1-V_{20} cultivated in summer. Maximum plant height (116 cm) and number of leaves (147) were found from cultivar Mini Anindyo Red (V_8) and Hybrid Tomato US440 (V_{18}) respectively. Maximum chlorophyll content, days to flower bud appearance and days to flowering were observed from cultivar BARI Tomato 6 (V_{19}); 53.0% chlorophyll, 40.3 days to bud appearance and 46.7 days for flowering. Maximum number of flower bud/bunch (6.0) and fruit/bunch (1.2) were observed from cultivar BARI Tomato 11(V_{20}) and Aran Chan Mini (V_{12}) respectively. Maximum number of branch/plant (5.7), number of bunch/plant (15.3), number of flower bud/plant (129.7), number of flower/plant (108.3), number of flower/bunch (6.7), number of fruit/plant (6.7), fruit length (22.8 cm), fruit diameter (61.3 mm), fruit weight (100 gm), yield/plant (667.1 gm), yield/plot (6.7 kg) and calculated yield/ha (22.3) were found from cultivar Mini Chika (V_{10}). Thus, cultivar Mini Chika (V_{10}) was found to be suitable for cultivation in summer.

Naz *et al.* (2011) conducted an experiment in Battal Valley of District Mansehra, Pakistan, to study growth, yield and nutritional composition of six exotic cultivars of tomatoes. Data on days to flowering and maturity, yield, TSS, ascorbic acid and titratable acidity was subjected to statistical analysis. Cultivar ‘Roma’ took minimum days to flowering (37.7 days) followed by ‘Rio Fuegd’ (39.0 days). Cultivar ‘Lyreka’ matured in 65.0 days followed by ‘Roma’ which took 67.7 days whereas cultivar ‘Yaqui’ took 85.0 days. Cultivar ‘Yaqui’ out-yielded other cultivars with 11.22 followed by ‘Avinash’ (9.52 tons ha-1). ‘Roma’ and ‘Rio Grand’ yielded lowest with 6.46 and 7.96 tons ha-1, respectively. Maximum TSS was observed in cultivar ‘Avinash’ (5.5) followed by Yaqui (5.4%) whereas it was found minimum in Roma (4.9 %) cultivar. ‘Lyreka’ have the most abundant ascorbic acid of 16.03 mg/100gm followed by

‘Rio Grand’ (15.86 mg/100 gm). The highest titratable acidity was found in ‘Yaqui’ (0.389%) while ‘Rio Grand’ was the lowest (0.313 %) in this respect.

Hazarika and Phookan (2005) evaluated 27 tomato cultivars in relation to growth, yield and quality under plastic rainshelter during summer season. Out of all the 27 cultivars, Yash recorded the maximum yield of 1.76 kg per plant followed by Arka Ahuti and Arka Ashish. Yash also recorded the maximum plant height, branch number, fruit set percentage and yield per plant.The flowers per inflorescence were found highest in cultivar BT_1. On the other hand, Arka Ahuti recorded the highest retention of matured fruits. Regarding the quality parameters, no single cultivar was found to be excellent in all the qualitative parameters. A wide range of variation was observed in both physical and chemical constituents of the fruits. However, Pusa Ruby and Arka Shreshta recorded the maximum TSS content, whereas the maximum amount of ascorbic acid was recorded in DRD-8014.

Shelby *et al.* (1978) compared two heat tolerant tomato breeding lines AV165 and Nagearlang, with the heat sensitive “Floradel” in respect of fruit set, pollen abortion and embryo sac abortion. They found that the two heat tolerant cultivars had a significantlt higher percentage of fruit set under both moderate and high temperature in spring and summer than “Floradel” but fruit set of all 3 cultivars was significantly lower at high temperature.

Hanna and Hernandez (1979) tested 23 tomato lines and varieties under high day (above 32.30^0c) and night (23.90^0c) temperature conditions for fruit set, flower drop and blind fruit using the three base flower on each of six clusters per plant. They found that BL6807 had a mean fruit set of 48.5%, CL 9-0-0-1 (33.6%) whereas L 401 had 1.2% only.

Hanna and Hernandez (1980) compared several characters related to heat tolerance in tomatoes 5 varieties under summer and spring seasons. In summer, average minimum temperature was 24^{0}C and maximum was 34.30^{0}C. In spring, average minimum temperature was 15.30^{0}C and maximum was 25.10^{0}C. The genotype BL6807 was least affected by high temperature; whereas, L401 and Chico III were most affected. The fruit set for L401 dropped from 78.1% in spring to 1.25 in summer. BL6807 had less flower drop and highest percentage of stained pollen in summer.

Diner *et al.* (1983) reported that decreased assimilate and carbon export at high temperature was greater in heat sensitive 'Roma VF' than heat tolerant 'Saladette' they also reported that poor fruit set was shown to be a result of inhibition of carbon transport from the leaf source, which was attributed to cellulose formation in the leaf petiole.

Rana and Kalloo (1989) evaluated 156 genotypes of tomato for number of flowers per cluster, percent fruit set, percent flower drop, number of fruit per truss, number of fruit per plant, sise of fruit yield plant^{-1} and stigma position in antheridial cone at high temperature (38-40^{0}Cday and 20-25^{0}C night). Out of that 138 genotypes could not set evan a single fruit and flower drop was 100%. The rest 18 genotypes have fruit setting rate of 46.97% to as low as 1.9%.

Phookan and Shadeque (1995) carried out an experiment with 29 tomato genotypes under plastic rain shelter in four plantings viz. 7 March, 7 May, 7 July, 7 September during 1991. Out of 29 genotypes 7 were common in all the four plantings. The crop planted in September gave the highest yield, being 19, 10, 74.66, and 67.88% higher than that planted in May, July and March respectively. The highest fruit setting (45.7%) was obtained in September planting, followed by May and March planting. At the time of flowering and fruit setting higher temperature significantly reduced the flower and fruit production.

Phookan *et al.* (1990) evaluated 29 genotypes of tomato (*Solanum lycopersicum*) against 8 different growth and yield attributing parameters under plastic house condition during summer season. ‘Vaishali’ tomato recorded the maximum yield (1.6 kg plant^{-1}) followed by 1.34 kg plant^{-1} in the genotype Sutton gram prolific. Mean values of at the characters showed wide variations for the plant height (46.0-95.00), branch number (5.00-10.50), flower number (21.00-95.00), fruit number (2.67-70.00), fruit setting percentage (11.92-73.95), yield plant^{-1} (0.210-600) and survival percentage (40-100).

Shamim *et al.* (2014) reported that drought is one of the most important abiotic stresses reducing crop growth and yield of tomato. Development of water stress tolerant cultivars through screening and selection is one important strategy to overcome this problem. In the present study, seeds of 120 local and exotic lines of tomato were allowed to germinate at varying levels of polyethylene glycol (PEG8000) induced water stress (PEG8000 0, 2.5%, 5.0% and 7.5%) for two weeks. Increasing PEG concentrations in the growth medium (water stress) caused a consistent decrease in seed germination percentage and seedling growth of all tomato cultivars. Moreover, a significant amount of genetic variability was found in all attributes of 120 genotypes of tomato. All lines/cultivars of tomato were ranked on the basis of relative water stress tolerance using 13 morphometric traits and categorized in four groups (tolerant, moderately tolerant, moderately sensitive, and sensitive) through multivariate analysis. Of 120 lines, 18, 25, 29 and 48 lines were ranked as tolerant, moderately tolerant, moderately sensitive and sensitive respectively. The germination percentage or speeds of germination were not found as effective indicator of genotypic differences for water stress at the seedling stage. Moreover, degree of water stress tolerance at the germination and seedling growth stage did not maintain in all tomato lines. Thus, it is not certain whether such variation is detectable at the later vegetative or reproductive growth stages. This needs to be further investigated. Overall, lines 19905, 19906, LA0716, and LA0722 were found to be water stress tolerant at least at early growth stages.

Muhammad *et al*. (1993) conducted an experiment with seven exotic cultivars of tomato namely Tanja, Chico III, F.M.-9, Eva, Riogrande, Savio and NARC-l including Roma local as check. For autumn cultivation cultivars Riogrande, NARC-l and F.M. 9 were found to be the best yielding 58.6, 55.4, and 54.5 t ha^{-1}, respectively. The cultivars showing promise during spring season were Roma, Chico III and Tanja having yields of 30.1, 27.9 and 27.0 t ha^{-1} respectively.

Hussain *et al.* (2001) evaluated ten cultivars of tomato on the basis of days to flowering, fruit setting and maturity period, number and weight of fruit per plant, length and width of fruit, average fruit weight, plant height and yield. The cultivars Nova Mech, Early Mech, Chico III, Nadir, Tanja and Sorrento were early in maturity whereas ‘Samarzano’ was a late maturing. The cultivar Tanja produced maximum fruit weight per plant (1.55 Kg) and gave the highest yield of 41.45 t/ha. It was followed by Chico-III and Sorrento which exhibited average yields of 40.32 and 39.13 t/ha respectively.

Abdelmageed *et al.* (2003) carried out different experiments under simulated temperature conditions in plant growth chambers at the Humboldt University of Berlin as well as under field conditions at the University of Khartoum, Sudan. Here only results obtained from experiments under controlled condition are presented. Plant height, leaf area, fresh and dry weight of leaves, stem and roots, number of clusters, number of flowers as well as the number of pollen grains per microscopic field were recorded. The reproductive processes in tomato were more sensitive to high temperatures than the vegetative ones. The number of pollen grains produced by the heat tolerant genotypes, were higher than the numbers produced by the heat sensitive genotypes. However, under field condition around Khartoum, Sudan other factors such as low relative humidity, insect and virus diseases as well as soil physical properties have also to be considered. Optimization of microclimate could be very important to ensure a good performance of new tolerant varieties cultivated in summer periods in Sudan.

Hussain *et al.* (2002) designed an experiment to study the morphological and yield behavior of nine exotic and one local cultivar of tomato under Islamabad conditions. Characters studied were time required to flowering, fruit setting, fruit ripening, yield plant^{-1} and yield ha^{-1}. Significant difference in the parameters except day to maturity wereobserved which could be attributed to inherited differences among cultivars. Cultivar marmande (TMV) took significantly minimum time (65.0 days) to ripen followed by S. marzano which ripened in 72.3 days. Cultivar polefemo ripened late (91.7 days) followed by marmande which took 87.7 days to ripen. Cultivar marmande TMV and marmande out yielded other cultivars with 64.29 and 62.99 t ha^{-1} respectively while poor yield was obtained in S. marzano (14.90 t ha^{-1}).

Dane *et al.* (1991) evaluated selected tomato *(Solanum lycopersicum)* genotypes for their fruit-setting ability under high-temperature field conditions. A temperature-controlled greenhouse study was conducted to determine the percent fruit set from the total number of flowers and fruit produced per plant. Ratings for set obtained under high temperature field conditions were significantly (P = 0.001) correlated with percent fruit set determined under similar greenhouse conditions. Most of the Asian Vegetable Research and Development Center (AVRDC) selections, Beaverlodge lines, 'Nagcarlan', and 'Red Cherry' could be considered heat-tolerant. Small-fruited, abundantly flowering genotypes were less affected by heat stress than larger-fruited cultivars. Prolonged periods of high temperature caused drastic reductions in pollen fertility in most genotypes, except 'Red Cherry' and *L. esculentum* var. *cerasiforme* (PI 190256). Stigma browning and stigma exsertion commonly occurred on all lines, except AVRDC CL-5915-553 and PI 190256. Diallel analyses indicated that pollen fertility and fruit set under high field temperatures were primarily under additive gene control.

Alam *et al.* (2010) studied on eight hybrid tomato lines bred for heat tolerance by the Olericulture Division, BARI to observe their fruit setting ability and yield performance under the hot, humid conditions at Olericulture Farm of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during summer 2005. Percent fruit set in the lines was found to be within the range of 30 to 45 except C-7 (3×7) in which this was 52.85. The tallest plants having larger number of branches and the lowest flower drop were also observed in C-7 (3×7). Pollen viability ranged from 27.63 to 61.52 percent among the hybrids. The highest weight of individual fruits (56.02 g) and firmness (1.41 kg) was observed in C-5 (2×5). The largest fruit in respect of length and diameter was produced by C-8 (5x5). No significant variation was found among the lines in respect of days to 50% flowering and percent TSS. Significant difference was observed for fruit number per plant ranging from 27 to 51. All of the lines produced remarkably high yields and C-7 (3x7) gave the highest yield per plant (1.73 kg) as well as per hectare (41.5 tons). The highest gross return (1867500 Tk/ha) and the maximum net return (1486748 Tk/ha) having the highest BCR (3.90) were recorded in C-7 (3×7).

Patwary *et al.* (2014) conducted an experiment at the Vegetable Research Field of Olericulture Division, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur during October 2006 to March 2007 and May to September 2007 to evaluate the performance of tomato (*Solanum lycopersicum*) genotypes in summer and winter seasons. Early flowering was observed in summer compared to winter. Pollen viability decreased greatly during summer ranging from 30.44 % in TMS 003 to 86.08 % in C 11 compared to that in winter (70.33 % in C 61 to 100.00 % in VRT 002). Fruit set (%) markedly decreased in summer, which ranged from 4.69 % in TMS 017 to 39.15 % in C 51 while it ranged from and 49.00 % in TMS 008 to 90.01 % in HT 017 during winter. During summer, fruit set (%) exhibited positive significant and correlation with viable pollen grains (%). Yield per plant ranged from 1224 g in C 61 to 2670 g in VRT 003 and 37 g in TMS 015 to 94 g in C 11 in winter. The genotypes HT 019, C 11, C 21, C 41, C 51, HT 016 and HT 017 exhibited a considerable heat tolerance in relation to fruit setting ability.

Hussain *et al.* (1990) conducted an experiment to study the performance of eleven tomato hybrids in an un-heated plastic tunnel during winter at NARC. Islamabad. The characters studied were time required for flowering. fruit setting, fruit maturity, number of fruits per plant, total fruit weight per plant, single fruit weight and yield m^{-2}. The variety Tobol' produced the maximum number of fruit per plant (50.8) and gave the highest yield of 13.6 kg m^{-2}. It was followed by 'Adaly'x and 'Dario: yielding 10.3 and 10.0 kg m^{-2} respectively.

Rahman *et al*. (2015) conducted an experiment at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh to test the impact of plant growth regulators on growth and yield of summer tomato. The experiment consisted of two tomato varieties *viz*. BARI Hybrid Tomato-4 and BARI Hybrid Tomato-8 and four types of plant growth regulator (PGR)*viz*.,(i) control (without PGR), (ii) 4-CPA (4-chlorophenoxy acetic acid), GA_3 (gibberellic acid) and 4-CPA + GA_3. The two-factor experiment was laid out in randomized complete block design with three replications. The results of the experiment revealed that significant variations were observed for most of the characters studied. At 75 DAT, the tallest plant (79.35 cm), number of flowers and fruits (38.11 and 19.04, respectively) $plant^{-1}$, individual weight (58.44 g) and fruit yield (22.75 t ha^{-1}) were found in BARI Hybrid Tomato-8. at 75 DAT the maximum plant height (87.90 cm), number of flowers and fruits (49.04 and 21.9, respectively) $plant^{-1}$, individual fruit weight (61.16 g) and fruit yield (27.28 t ha^{-1}) were found when 4-CPA + GA_3 applied together whereas the minimum for these characters were recorded from control plants. In case of combined effect of variety and plant growth regulator, the maximum plant height (87.90 cm), number of flowers and fruits (49.04 and 21.91, respectively) $plant^{-1}$, individual fruit weight (61.16 g) and fruit yield (27.28 t ha^{-1}) were observed in BARI Hybrid Tomato-8 when treated with 4-CPA + GA_3 together, and the minimum for all these parameters were found in control plants. The results of the present study suggest that both 4-CAP and GA_3 together can be practiced for increasing summer tomato production for both the varieties.

Smit and Combrink (2005) studied on problems with reduced yields owing to poor pollination where tomatoes are grown out-of-season in low cost greenhouses, motivated this study. Greenhouse tomatoes were planted in acid washed river sand. Four balanced nutrient solutions, with different boron (B) levels (0.02; 0.16; 0.32 and 0.64 mg L^{-1} were applied. The second flower cluster was covered with a transparent plastic bag and three relative humidity (RH) levels were applied to the isolated clusters. Dry (10% RH), normal (60-75% RH) and moist (85-97% RH) air was constantly blown into the bags at ± 50 ml min-I. As a third factor at two levels, some of the clusters were vibrated daily with an electric vibrator (Poli-bee) and the controls not. The number of flowers per cluster, fruits per cluster, fruit set, weight of the cluster (yield), average fruit weight, seed production, fruit weight per number of seeds formed and fruits with blossom-end-rot (BER) were evaluated. Higher B-Levels improved fruit set where trusses were not vibrated. A high RH reduced the number of seeds that developed per cluster, lowered cluster weights and the number of fruits per cluster and increased the incidence of BER. More BER developed on bigger fruit. Fruit set improved with cluster vibration, associated with more seeds and bigger fruit, especially under less humid conditions.

Nahiyan *et al.* (2014) conducted an experiment to evaluate the performance of sixteen tomato varieties at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period of November 2012 to March 2013. The genotypes including varieties and breeding materials were given code numbers from V_1 to V_{16}. Maximum number of bunch (13.7/plant), fruits (33.0/plant) and yield (2.2 kg/plant) were observed in V_8 plants. On the other hand, V_{11} was found to show field resistance against a number disease pathogens like *Phytophthora infestans*, *Alternaria solani*, *Clavibacter michiganinsis*, Tomato Mosaic Virus (TMV), Tomato Bushy Stunt Virus (TBSV), *Septaria lycopersici*. However, the resistance or tolerance whatever was found needs to be determined through specific race induced diseases under controlled environment.

Ghosh *et al.* (2010) studied the F_2 segregating generations of exotic tomato hybrids to measure variability, character association and path coefficient analysis. Analysis of variance for each trait showed significant differences among the genotypes. Very little differences were observed between phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV) for the traits days to first flowering (pcv=9.21, gcv=7.82), fruit length (pcv=17.14, gcv=14.84) and fruit diameter (pcv=17.10, gcv=14.92). High heritability (>50%) was observed for all the yield contributing characters except flowers per cluster (47.83%). High heritability associated with high genetic advance was observed for fruit clusters per plant (105.11), fruits per plant (103.43), branches per plant (34.49), fruits per cluster (47.43), individual fruit weight (77.73) and fruit yield per plant (108.25). Selection for such traits might be effective for the fruit yield improvement of tomato. Significant positive genotypic and phenotypic correlation was observed between plant height at first flowering, flowers per plant, fruits per cluster, fruit clusters per plant, fruits per plant with fruit yield per plant. Fruits per plant showed the highest positive direct effect (1.096) on fruit yield per plant followed by individual fruits per plant (0.674). Direct selection may be executed considering these traits as the main selection criteria to reduce indirect effect of the other characters during the development of high yielding tomato variety.

Dar *et al.* (2012) planned and executed an experiment during spring and summer seasons of 2007 to 2010 at Vegetable Experimental Farm, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and

Technology, Main Campus, Chatha. The experimental material include 60 diverse genotypes of tomato collected from various places including Indian Institute of Vegetable Research Institute (IIVR) Varanasi Uttar Pradesh and some local cultivars. The observations were recorded on yield and quality traits to generate information regarding the extent of genetic variability, heritability and expected genetic advance. Analysis of coefficient of variation revealed that the magnitude of the phenotypic coefficient of variation was higher than that of the genotypic coefficient of variation for all the seven characters under study. The highest values of the phenotypic coefficient of variation (PCV) were recorded for fruit yield, number of locules per fruit and pericarp thickness. High genotypic coefficients of variation (GCV) were recorded for yield polygalacturonase activity and pericarp thickness. High heritability was recorded for most of the characters, namely, pericarp thickness, polygalacturonase activity and alcohol insoluble solids. The above results are quite encouraging for advancing in tomato breeding.

Karim *et al.* (2015) conducted a field experiment at the Horticulture Farm in the Department of Horticulture, Bangladesh Agricultural University, Mymensingh to evaluate the influence of different levels of 4-chlorophenoxy acetic acid on growth and yield potential of tomato during summer. The two-factor experiment viz., Factor A: four different concentrations of 4-chlorophenoxy acetic acid (4-CPA) i.e., concentrations of 4-CPA were (i) 0 ppm (without 4-CPA), (ii) 20 ppm, (iii) 40 ppm and (iv) 60 ppm; and Factor B: two varieties of summer tomato namely, BARI Hybrid Tomato-4 and 8. The experiment was laid out in randomized complete block design with three replications. At harvest, the tallest plant (78.53cm), number of flowers and fruits (35.11and 18.10, respectively) plant^{-1}, fruit yield plant^{-1} and ha^{-1} (1.12 kg and 21.98 tons, respectively) were found in BARI Hybrid Tomato-8. They suggested that 4-CAP at 60 ppm can be practiced for increasing summer tomato production for both the varieties.

CHAPTER III

MATERIALS AND METHODS

Details of the experimental materials and methods followed in the study are presented in this chapter. The experiment was carried out during the period from May 2015 to August 2015, to evaluate the performance of 22 summer tomato germplasm under polyshed condition.

3.1 Experimental site

The experiment was accomplished at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, during the period from 2015 May to August 2015. Location of the site is $23^0$74' N latitude and $90^0$35' E longitudes with an elevation of 8 meter from sea level (UNDP - FAO, 1988) in Agro-Ecological Zone of Madhupur Tract (AEZ No. 28) with wet summer and dry winter.

3.2 Characteristics of soil

The experimental soil belongs to the Modhupur Tract under AEZ No.28 (UNDP, 1988).The selected experimental plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of soil under experimental plot were analyzed in the SRDI, Soil testing Laboratory, Khamarbari, Dhaka. The soil of the experimental field initially had a pH of 6.9, organic carbon 1.05%, total N 0.08%, available P 12.78 ppm, exchangeable K 43.29 ppm, available S 23.74 ppm, available B 0.36 ppm.

3.3 Climate

Experimental site was located in the subtropical climatic zone, set aparted by summer during May to August (Kharif season). Also under the sub-tropical climatie, which is characterized by high temperature, high humidity, heavy precipitation with occasional gusty winds and relatively long in kharif season (April-September) and scanty rainfall associated with moderately low temperature, low humidity and short day period during Rabi season (October-

March). Weather information regarding the atmospheric temperature, relative humidity, rainfall, sunshine hours and soil temperature prevailed at the experimental site during the entire period of investigation.

3.4 Treatments of the experiment

The experiment was conducted to study the performance of twenty two summer tomato germplasm on growth, yield and quality attributes. The germplasm used in this experiment were –

Germplasm	Source
G_1 (ACI summer King) (check)	ACI, Bangladesh
G_2 (BINA Tomato 2) (check)	BINA, Bangladesh
G_3 (BINA Tomato 3) (check)	BINA, Bangladesh
G_4 (AVTO- 09809)	ACI, Bangladesh
G_5 (AVTO-1007)	ACI, Bangladesh
G_6 (AVTO-1009)	ACI, Bangladesh
G_7 (AVTO-1002)	ACI, Bangladesh
G_8 (AVTO-201)	ACI, Bangladesh
G_9 (BARI-4) (Check)	BARI, Bangladesh
G_{10} (Lakshi)	India
G_{11} (JP-13)	Japan
G_{12} (JP-26)	Japan
G_{13} (JP-27)	Japan
G_{14} (Sweden-2)	Sweden
G_{15} (Netherland-13)	Netherlands
G_{16} (Sweeden-5)	Sweden
G_{17} (Apple Netherlands)	Netherlands
G_{18} (SAU san-001)	Bangladesh
G_{19} (MAL-3)	Malaysia
G_{20} (Purple-4)	Netherlands
G_{21} (CSN-1)	Netherlands
G_{22} (Orange4)	Netherlands

3.5 Raising of seedlings

Seedlings of summer tomato were raised under special care for each bed. The soil of seed bed was ploughed well and the clods were broken into small pieces and converted into loose, friable to obtain good tilth. The seed bed was dried in the sun to prevent damping off disease of seedling. All weeds, stubbles and dead roots of crops were removed carefully. Seeds were sown in seed bed on 5th May, 2015 to get seedlings of 30 days old at the time of transplanting. Weeding, mulching and watering were done to provide favorable condition for good growth and raising quality seedlings.

3.6 Design and layout of the experiment

The experiment was laid out in randomized complete block design (RCBD) with three replications. Seedlings were sown on 3rd June, 2015 in 3 m × 1 m sized bed. Row to row distance was maintained 60 cm and plant to plant distance was at 40 cm. There were 10 plants accommodated in each plot.

3.7 Spacing and plot size

40 cm x 60 cm spacing was maintained. Each of the plot size was 3.0 m ×1.0 m and 30 cm was left for irrigation and drainage between two beds. Thirty days old seedlings were transplanted in plots under transparent polyethylene shed tunnel.

3.8 Land preparation

The land was first opened on May, 2015 and was ploughed with a tractor and kept open to the sunlight for days. The experimental plot was thoroughly prepared by ploughing and cross ploughing with a power tiller followed by laddering to provide a good tilth and favorable condition for summer tomato production. Weeds and stubbles were removed from the field and big clods were broken into tiny pieces. The experimental field was leveled and the experimental plot was laid out according to plan.

3.9 Fertilizer applications

Manures and fertilizers were applied at the rate of cowdung 12 t ha^{-1}, urea 450 kg ha^{-1}, Triple Super Phosphate (TSP) 250 kg ha^{-1} and Muriate of Potash (MoP) 260 kg ha^{-1} (BARI, 2011). The entire amount of organic manure, TSP and half of the MoP were applied during final land preparation. The remaining half of MoP and entire urea were applied in two equal installments, 1st at 15 days after planting and 2nd at flowering.

3.10 Seedling transplanting

Healthy and uniform sized seedlings 30 days old were transplanted in the experimental plot on 3rd June, 2015. To avoid root injury, the seedlings were watered in the morning before uprooting them in the afternoon. Then they were planted in the experimental plot maintaining a spacing of 60 cm between rows and 40 cm plant to plant accommodating 10 plants per plot. Transplanting was done in the afternoon. The seedlings were watered immediately after transplanting.

3.11 Intercultural operations

3.11.1 Weeding and watering

Weeding and mulching were executed as and whenever necessary to keep the crop free from weeds, for better soil aeration and to break the crust. It also preserved the soil moisture.

Frequency of watering depended upon soil moisture status by observing visually. However, water logging was avoided as it was detrimental to plants.

3.11.2 Plant protection

Bird, normal pests and diseases were observed in summer tomato field. When presence of insects and diseases were noticed some organic pesticide were sprayed and a net was used to save summer tomatoes from bird.

3.11.3 Gap filling and staking

When the tomato seedlings were well established, the soil around the base of each seedling was pulverized. Gap filling was done by healthy seedlings of the same stock material grown in nearby plot where initial planted seedlings failed to survive. After 30 days of transplanting when the tomato plants were well established, staking was performed using jute sticks to keep the plants erect.

3.11.4 Plant protection measures

Plant protection measures were done whenever they were necessary.

Disease and insect control:

Tomato leaf curl virus and tomato mosaic virus was found on few plants and these are controlled by spraying Dithane-M45. Insects were controlled by using Malathion 57 EC (2 times at 25 and 32 days after transplanting (DAT).

3.12 Harvesting of fruits

Mature fruits were harvested when fruits turned to red in color with waxy layer on the surface of fruits. Fruits were harvested from last week of July 2015 to first week of August 2015.

3.13 Data collection

Data were collected with the following parameters:

1. Plant height (cm)
2. Number of leaves plant^{-1}
3. Number of branches plant^{-1}
4. Chlorophyll Content (%)
5. Days of first flowering
6. Number of flowers per plant^{-1}
7. Number of fruits plant^{-1}
8. Fruit length (cm)
9. Fruit diameter (cm)
10. Single fruit weight (g)
11. Yield plant^{-1} (kg)
12. Yield (ton ha^{-1})

3.13.1 Plant height (cm)

The height of the plant was measured by placing a meter scale from ground level to the tip of the outer longest leaf of an individual plant. Thus, mean of five selected plants of a plot was recorded and expressed in centimeter (cm).

3.13.2 Number of leaves

The number of leaves per plant was counted individually after 20 days of transplanting and continued upto 48 days after transplanting at an interval of seven days.

3.13.3 Number of branches plant^{-1}

Number of branches per plant was recorded by counting all branches of five plants after 40 days of planting and mean was calculated.

Branch length of each plant was measured in cm by using meter scale and mean was calculated.

3.13.4 Chlorophyll content

Chlorophyll Meter (SPAD-502) was used for measuring chlorophyll content (%).

3.13.5 Days to first flowering

Date of first flowering was recorded and the number of days required for first flowering was calculated.

3.13.6 Number of flowers plant^{-1}

The number of total flowers was recorded from the each plant throughout the plant growth.

3.13.7 Number of fruits plant^{-1}

Number of fruit per plant was recorded by counting all plants of fruits from each plant of fruits and mean was calculated. After 60 days of transplanting number of fruit per plants was counted.

3.13.8 Fruit length

The length of fruit was measured with a slide calipers from the neck of the fruit to bottom of five selected marketable fruits from each plant and their average was calculated in centimeter.

3.13.9 Fruit diameter

Fruit length and diameter were measured using Digital Caliper -515 (DC-515) in centimeter (cm).

3.13.10 Single fruit weight

Fruit weight was measured by Electronic Precision Balance in gram (g). Total fruit weight of each pot was obtained by addition of weight of the total fruit number and average fruit weight was obtained from division of the total fruit weight by total number of fruit.

3.13.11 Yield plant^{-1}

Fruit yield per plant was calculated from weight of total fruits divided by the number of total plants.

3.13.12 Yield hectare^{-1}

Fruit yield per hectare was computed and expressed in ton hectare^{-1}.

3.14 Statistical analysis

Collected data were statistically analyzed using MSTAT-C computer package program. Mean for every treatments were calculated and analysis of variance for each one of characters was performed by F–test (Variance Ratio).

Difference between treatments was assessed by least significant difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The results of morpho-physiological study of 22 summer tomato germplasm under polyshed condition have been presented with possible interpretations under the following headings:

4.1 Plant height

Plant heights of different tomato germplasm showed significant variation in the current study (Table 1). Among the germplasms the tallest plant (191.2 cm) was observed from G_{13} (JP-27) and the shortest plant (32.97 cm) was observed from G_{21} (CSN-1).

This might be due to genetic makeup of germplasm which may vary from germplasm to germplasm. Tomato introductions and adaptation trials have been undertaken in many environments, as a way to determine genotype environment interaction, stability and genetic diversity including increasing crop productivity (Chaerani, 2006). The tallness, shortness and other morphological differences are varietal characteristics, which are controlled and expressed by certain genes (Fayaz *et al.*, 2007). Olaniyi *et al.* (2010) also found that plant height varied due to the varietal differences. This was in agreement with the present result. Phookan *et al.* (1990) found that plant height of tomato varied in summer under plastic house condition. Similar opinion was put forwarded by Hossain *et al.* (2002) in brinjal.

4.2 Number of leaves

The number of leaves plant^{-1} of summer tomato significantly varied among the germplasm (Table 1). The maximum number of leaves (60.20) was recorded from G_4 (AVTO- 09809) whereas the minimum number of leaves (22.13) was recorded from G_{21} (CSN-1).

The variation may be due to germplasm characteristics. More number of branches results in more production of leaves, the size of the leaf and number of leaves per plant decides the efficiency of photosynthesis activity which contributed towards better growth and yield. The results were in confirmation with Deepa and Thakur (2008), Arun *et al*. (2004). Leaves are very important vegetative organs, as they are chiefly concerned with the physiological processes, photosynthesis and transpirations. Thus it influenced the growth of a plant very much and is positively correlated with the yield of a plant.

4.3 Number of branches

The number of branches plant^{-1} of summer tomato is an important parameter of growth. Germplasm had significant effect on number of branches plant^{-1} of summer tomato (Table 1). Maximum number of branches plant^{-1} (26.00) was found from G_4 (AVTO- 09809) whereas minimum (5.33) was found from G_{17} (Apple Netherlands) which was statistically similar with G_{20} (Purple-4), G_{18} (6.67), G_{12} (8.00) and G_9 (7.33).

Differences in number of branch among the genotypes might be due to the genetical make up of the genotypes. Alam *et al.* (2010) showed the number of branches per plant differed significantly among the lines of tomato at final harvest and it varied from 4.3 to 6.7 per plant. Phookan *et al.* (1990) reported similar results. Parvej *et al.* (2010) found the above microclimatic variabilities inside polyhouse favoured the growth and development of tomato plant through increased number of branches plant^{-1} over the plants grown in open field. More number of branches results in more production of leaves, the size of the leaf and number of leaves per plant decides the efficiency of photosynthesis activity which contributed towards better growth and yield of tomato.

Table 1. Performance of different tomato germplasm on plant height, number of leaves plant^{-1} and number of branches plant^{-1}

Germplasm	Plant height (cm)		No. of leaves plant^{-1}		No. of branches plant^{-1}	
G_1	34.9	p	32.27	jk	17.00	cd
G_2	67.3	m	45.47	gh	21.33	b
G_3	52.7	o	39.33	i	14.67	cde
G_4	97.53	hi	60.20	a	26.00	a
G_5	72.3	lm	40.00	i	16.67	cd
G_6	82.1	jk	42.80	hi	17.33	c
G_7	101	gh	49.60	ef	10.6	f-j
G_8	57.6	no	39.67	i	9.333	g-k
G_9	110.8	f	34.67	j	7.333	Jkl
G_{10}	104.8	g	50.20	de	10.67	f-j
G_{11}	185.1	b	26.13	l	11.33	e-i
G_{12}	84.33	j	48.00	efg	8.000	i-l
G_{13}	191.2	a	55.73	b	12.67	efg
G_{14}	176.5	c	55.53	bc	12.00	e-h
G_{15}	127.8	d	40.07	i	13.33	def
G_{16}	118.7	e	49.73	ef	17.333	jkl
G_{17}	114.2	ef	51.73	cde	5.333	l
G_{18}	67.57	m	46.13	fgh	8.667	h-l
G_{19}	77.03	kl	53.80	bcd	10.00	f-k
G_{20}	60.63	n	30.13	k	6.667	kl
G_{21}	32.97	p	22.13	m	11.33	e-i
G_{22}	95.13	i	30.13	k	12.00	e-h
$LSD_{(0.01)}$	**5.1**		**3.989**		**3.992**	
Significant level	**		**		**	
CV%	**3.3**		**5.64**		**19.76**	

** Significant at 1% level

Germplasms: G_1= ACI Summer king (check); G_2= BINA tomato 2 (check); G_3= BINA tomato 3 (check); G_4= AVTO-09809; G_5= AVTO-1007; G_6= AVTO- 1009; G_7= AVTO-1002; G_8= AVTO-201; G_9= BARI-11 (Jhumka); G_{10}= Laksi; G_{11}= JP-13; G_{12}= JP-26; G_{13}= JP-27; G_{14}= Sweeden-2; G_{15}= Netherlands-13; G_{16}= Sweeden-5; G_{17}= Apple Netherlands; G_{18}= SAU san-001; G_{19}= MAL-3; G_{20}= Purple-4; G_{21}= CSN-1 and G_{22}= Orange- 4.

4.4 Chlorophyll content

Chlorophyll content (%) on leaves (SPAD reading) showed significant variation among the germplasms (Table 2). The highest chlorophyll content (73.2 %) on leaves was observed from G_{12} (JP-26) which was statistically identical with G_5

(71.9 %) germplasm whereas the lowest chlorophyll content (31.4 %) on leaves was observed from G_{13} (JP-27) which was statistically similar with G_7 (36.1 %) germplasm.

The chlorophyll is the green pigment of plant, which is essential for photosynthesis. At least nine types of chlorophyll may be distinguished. Among them, chlorophyll-a and chlorophyll-b are best known except pigment containing bacteria (Bonner and Galstun, 1952). Chlorophyll influences the growth of a plant which is correlated with the yield.

Leaf chlorophyll content is often highly correlated with leaf N status, photosynthetic capacity and RuBP carboxylase activity (Evans, 1998; Seemann *et al.*, 1987); a loss in chlorophyll coincides with development of grain filling. There were also significant differences in the amount of chlorophyll content of leaves in the four different growths, development stages, the age groups and on different plant species (Blackburn, 1998; Yang and Ko, 1998). The variation in the chlorophyll content is an indication of the differences in the growth habit of the plant varieties as similarly found in cowpeas by Olotuah and Fadare (2012).

4.5 Days to first flowering

Significant variation was found on days to first flowering with different summer tomato germplasms (Table 2). The longest period (31.3 days) was required for first flowering in G_7 (AVTO-1002) whereas shortest period (19.3 days) in G_{18} (SAU san-001) which was statistically similar with G_{17} (20.7 days) and G_4 (20.7). The result indicated that G_7 was early flowering and G_{18} was the late one. Early flowering is required to increase cropping intensity.

This difference in flower initiation was due to its genotypic characters. Georgina (1969) reported that the pre-flowering period ranging from 56 to 76 days among the genotypes under his study. In Mymensingh condition, Biswas and Mallik (1989) studied flowering period of 18 promising tomato cultivars and period a range of 66 to 82.67 days for 1st flowering. Islam (2014) found that the germplasm BINA Tomato-6 took long time to first flowering may be due to its vegetative growth required more time than other varieties. High temperature probably interrupted the process of flowering (Ahmad, 2002). Aung (1976); Charles and Harris (1972) and Kuo *et al.* (1979) also reported that flower formation is affected by temperature stress.

4.6 Number of flower

The number of flowers plant^{-1} significantly varied among different tomato germplasms (Table 2). The highest number of flowers plant^{-1} (64.0) was found from G_4 (AVTO-09809) and the lowest (20.3) from G_{17} (Apple Netherlands) which was statistically similar with G_{16} (21.0), G_{19} (25.0), G_{20} (22.3) and G_{12} (25.3).

The variation in number of flowers per plant was possibly due to their genotypic characteristics. The number of flower per plant is an important character, which has the significant role to determine the yield of tomato. The production of flower per plant might be affected by the different cultivars. Aung (1976) and Stevens (1979) reported that an extent of decreased number of flower depends on cultivars. Parvej *et al.* (2010) found that polyhoused plants had higher number of flowers plant^{-1} over open field condition. Charles and Harris (1972) also reported decrease of flower production with increased temperature. Mehraj *et al.* (2014) was also found that number of flowers plant^{-1} had significant variation among the brinjal varieties. It was observed that tomato germplasms have the ability to produce flower and fruit during the summer season but the number of harvested fruit is very low. It may very high day temperature or heavy rainfall. Plastic tunnel was used to protect the pollen from washed away due to the heavy rainfall, so the temperature might be acted as a vital fact for fruit formation.

Table 2. Performance of different tomato germplasm on chlorophyll content, days to first flowering and number of flowers plant^{-1}

Germplasm	Chlorophyll content (%)		Days to first flowering		No. of flowers plant^{-1}	
G_1	50.2	ef	23.7	hij	34.7	fghi
G_2	55.9	cde	22.0	kl	38.0	def
G_3	50.4	ef	27.3	cde	31.3	ghij
G_4	63.7	b	20.7	lm	64.0	a
G_5	71.9	a	29.7	b	30.7	ij
G_6	52.7	def	27.3	cde	39.3	cdef
G_7	36.1	jk	31.3	a	36.0	efgh
G_8	49.8	efg	26.3	ef	31.3	hij
G_9	46.4	fgh	22.7	jk	46.0	b
G_{10}	57.2	cd	28.3	bc	36.3	efg
G_{11}	43.7	ghi	27.3	cde	39.0	cdef
G_{12}	73.2	a	26.7	de	25.3	klm
G_{13}	31.4	k	28.0	cd	30.0	ijk
G_{14}	54.8	de	27.0	cde	42.0	bcd
G_{15}	58.2	bcd	24.7	gh	40.0	cde
G_{16}	37.8	ij	23.0	ijk	21.0	m
G_{17}	38.6	ij	20.7	lm	20.3	m
G_{18}	39.7	ij	19.3	m	29.0	jkl
G_{19}	48.3	fgh	24.3	hi	25.0	lm
G_{20}	55.1	de	25.0	fgh	22.3	m
G_{21}	61.5	bc	26.0	efg	43.3	bc
G_{22}	42.8	hi	23.0	ijk	31.3	ghij
$LSD_{(0.01)}$	**5.7**		**1.5**		**4.6**	
Significant level	**		**		**	
CV%	**6.7**		**3.5**		**11.4**	

** Significant at 1% level

Germplasms: G_1= ACI Summer king (check); G_2= BINA tomato 2 (check); G_3= BINA tomato 3 (check); G_4= AVTO-09809; G_5= AVTO-1007; G_6= AVTO- 1009; G_7= AVTO-1002; G_8= AVTO-201; G_9= BARI-11 (Jhumka); G_{10}= Laksi; G_{11}= JP-13; G_{12}= JP-26; G_{13}= JP-27; G_{14}= Sweeden-2; G_{15}= Netherlands-13; G_{16}= Sweeden-5; G_{17}= Apple Netherlands; G_{18}= SAU san-001; G_{19}= MAL-3; G_{20}= Purple-4; G_{21}= CSN-1 and G_{22}= Orange- 4.

4.7 Number of fruits

The number of fruits plant^{-1} significantly varied in different germplasm of summer tomato (Table 3). The maximum number of fruits plant^{-1} (40.0) was found from G_4 (AVTO-09809) and minimum number of fruits plant^{-1} (5.33) was found from G_{20} (Purple-4) which was statistically similar with G_6 (8.0), G_{12} (9.33), G_{13} (10.67), G_{17} (9.33), G_{22} (9.33) and G_{18} (8.0).

Germplasm itself is a genetic factor which contributes a lot in producing yield and yield components of a particular crop. Yield components are directly related to the germplasm and neighboring environments in which it grows. The marked variation among the germplasms in terms of number of fruits per plant was possibly due to the genetical potentiality of the germplasms. The present findings agree with the report of Bhangu and Singh (1993).

Nandpuri *et al.* (1977); Prasad and Prasad (1979); Islam and Khan (1991) found significant genotypic variation for the number of fruits per plant of tomato. Mehraj *et al.* (2014) also found similar number of fruit per plant from the germplasm of Sweden-2 (162.3) while they studied on summer tomato. Phookan *et al.* (1990) evaluated the performance of 29 tomato hybrids on different growth and yield attributing parameters under plastic house condition during the summer season and found fruit number ranging from 2.67 to 70.0.

4.8 Fruit length

Significant variation was found for fruit length (cm) among summer tomato germplasms (Table 3). Among the germplasms of summer tomato G_{17} (Apple Netherlands) gave the longest fruit (43.1 cm) while G_{13} (JP-27) gave the shortest fruit length (21.4 cm) which was statistically similar with G_{10} (22.3 cm) and G_7 (23.2).

This is may be due to the genetic build up of germplasms. Islam (2014) found that the maximum fruit length (4.71 cm) was produced by BARI Hybrid Tomato-5. Mehraj *et al.* (2014) found maximum fruit length (22.8 cm) from cultivar Mini Chika. Thus, cultivar Mini Chika was found to be suitable for cultivation in summer. Parvej *et al.* (2010) also found that polyhoused plants had higher fruit length over open field condition.

4.9 Fruit diameter

Significant variation was recorded for fruit diameter (cm) among summer tomato germplasms (Table 3). The maximum fruit diameter (13.5 cm) was found from G_{11} (JP-13) which was statistically similar with G_{16} (12.8 cm) and minimum fruit diameter (5.2 cm) was found from G_2 (BINA tomato-2) which was statistically similar with G_5 (6.1 cm).

The variation may be due to genetical. Varietal influence on fruit diameter was reported by Bhangu and Singh (1993). Islam (2014) found that the minimum fruit length in variety BINA Tomato-6 and maximum in variety BARI Hybrid tomato-5 may be due to its genetical characteristics. Mehraj *et al.* (2014) were observed maximum fruit diameter (61.3 mm) from cultivar Mini Chika. Thus, cultivar Mini Chika was found to be suitable for cultivation in summer.

Table 3. Performance of different tomato germplasm on number of fruits plant^{-1}, fruit length and fruit diameter

Germplasm	Number of fruits plant^{-1}		Fruit length (cm)		Fruit diameter (cm)	
G_1	16.00	c-g	25.2	ijk	7.0	ij
G_2	14.67	d-h	27.6	gh	5.2	k
G_3	18.67	bcde	25.1	ijk	6.4	ij
G_4	40.00	a	33.8	c	11.9	bc
G_5	21.33	bc	31.1	de	6.1	jk
G_6	8.00	ij	26.1	hi	7.6	hi
G_7	17.33	b-f	23.2	klm	9.4	efg
G_8	20.00	bcd	26.1	hi	10.3	de
G_9	13.33	e-i	23.5	jkl	8.3	gh
G_{10}	13.33	e-i	22.3	lm	11.3	cd
G_{11}	21.33	bc	33.0	cd	13.5	a
G_{12}	9.33	hij	25.1	ijk	10.1	e
G_{13}	10.67	ghij	21.4	m	6.8	ij
G_{14}	21.33	bc	25.3	ijk	8.3	gh
G_{15}	13.33	e-i	25.4	hij	8.6	fgh
G_{16}	18.67	bcde	26.7	ghi	12.8	ab
G_{17}	9.33	hij	43.1	a	10.6	de
G_{18}	8.00	ij	39.0	b	9.6	ef
G_{19}	12.00	fghi	30.8	e	8.4	fgh
G_{20}	5.33	j	27.1	ghi	11.9	bc
G_{21}	22.67	b	28.7	fg	8.5	fgh
G_{22}	9.33	hij	30.2	ef	7.1	ij
$LSD_{(0.01)}$	**5.402**		**1.9**		**1.1**	
Significant level	**		**		**	
CV%	**20.97**		**7.3**		**4.1**	

** Significant at 1% level

Germplasms: G_1= ACI Summer king (check); G_2= BINA tomato 2 (check); G_3= BINA tomato 3 (check); G_4= AVTO-09809; G_5= AVTO-1007; G_6= AVTO- 1009; G_7= AVTO-1002; G_8= AVTO-201; G_9= BARI-11 (Jhumka); G_{10}= Laksi; G_{11}= JP-13; G_{12}= JP-26; G_{13}= JP-27; G_{14}= Sweeden-2; G_{15}= Netherlands-13; G_{16}= Sweeden-5; G_{17}= Apple Netherlands; G_{18}= SAU san-001; G_{19}= MAL-3; G_{20}= Purple-4; G_{21}= CSN-1 and G_{22}= Orange- 4.

4.10 Single fruit weight

The single fruit weight (g) of summer tomato significantly varied in different germplasms (Table 4). The highest single fruit weight (100.70 g) was found from G_4 (AVTO-09809) and lowest single fruit weight (21.30 g) was found from G_{13} (JP-27) which was statistically identical with G_{12} (21.40 g).

Germplasm is the key component to produce higher yield of tomato depending upon their differences in genotypic characters. Mehraj *et al.* (2014) found significant variation in individual fruit weight among the tomato varieties. Ahmad (2002) also found a significant variation among the 25 heat tolerant hybrids which supports the findings of the present study. Reddy and Reddy (1992) observed a wide range of variation of individual fruit weight ranged from 1.25 kg to 1.58 kg. Das *et al.* (1998) observed a considerable range of variation among 23 diverse genotypes of tomato with respect to individual fruit weight. Varietals influence on individual fruit weight was reported by Bhangu and Singh (1993). Islam (2014) was recorded that significant variation among the varieties in terms of individual fruit weight. The maximum individual fruit weight (70.27g) was observed in the variety BARI Hybrid tomato-5. Variation in fruit weight by different cultivars have also been reported by Gabal *et al.* (1985), Ermolova (1984), Horie (1985), Glavinich *et al.* (1982) and Khokhar *et al.* (1988).

4.11 Yield plant^{-1}

It was observed from the result of the experiment that the summer tomato germplasm showed significant variation for yield (kg) plant^{-1} (Table 4). The highest yield plant^{-1} (4.67 kg) was recorded from G_4 (AVTO-09809) whereas the lowest yield plant^{-1} (0.64 kg) was recorded from G_{20} (Purple-4).

Germplasm is the key component to produce higher yield of tomato depending upon their differences in genotypic characters, growth process and off course the prevailing environmental conditions during the growing season. This differences may be due to different germplasm performances. Hossain (2001) also reported that the variety BARI tomato 7 produced the highest yield. Mehraj *et al*. (2014) observed that yield per plant were also varied significantly among the tomato varieties. Yield of tomato varied depending on the level of heat tolerance of the hybrids (Baki, 1991). The variations of yield may also depend on genetic differences among the varieties, since they were grown under the same environmental conditions (Olaniyi and Fagbayide, 1999). The current study showed resemblance to the study carried out by Tika *et al*. (2011) who also found that the highest yield from tomato variety All Rounder (86.6 ton/ha) followed by Srijana (80.8 ton/ha). Similar marked differences in fruit yield of tomato varieties were reported by Mishra and Lal (1998) and Rida *et al*. (2002). The trend observed in the previous studies and results of the present study indicated that the higher yield depends on the number of fruits and weight of fruits per plant.

4.12 Yield ton ha^{-1}

Summer tomato germplasm showed significant variation for yield ha^{-1} (ton) (Table 4)**.** Maximum yield ha^{-1} (35.73 ton) was found from G_4 (AVTO- 09809) and minimum yield ha^{-1} (25.57 ton) was found from G_{20} (Purple-4) which was statistically similar with G_{12} (25.93 ton ha^{-1}).

This difference may be due to different germplasm performances. Hossain (2001) also reported that the variety BARI tomato 7 produced the highest yield. Variation in growth and yield is the genotypic attribution which even varies from line to line and clone to clone. The results of Hussain *et al*. (1990), Hussain *et al*. (2002), Gabal *et al*. (1985), Khokhar *et al*. (1988) and Chaudhry *et al*. (1999) are in confirmation with present statement of yield differences for different germplasm. Germplasm is the most important factor in tomato production. Selection of potential germplasm, planting in appropriate method and application of optimum amount of nutrient elements, can play an important role in increasing yield and national income.

Table 4. Performance of different tomato germplasm on single fruit weight, yield plant^{-1} and yield ha^{-1}

Germplasm	Single fruit weight (g)		Yield plant^{-1} (kg)		Yield ha^{-1} (ton)	
G_1	33.20	i	1.51	e-i	27.30	i
G_2	61.60	efg	1.84	c-i	28.13	gh
G_3	54.30	h	1.99	b-h	28.97	de
G_4	100.70	a	4.67	a	35.73	a
G_5	62.90	def	2.59	b-f	30.30	b
G_6	82.90	b	1.65	d-i	27.93	h
G_7	61.80	efg	2.81	bcd	29.13	cde
G_8	59.10	fg	2.70	b-e	29.40	c
G_9	27.90	j	1.04	hi	26.93	ij
G_{10}	82.20	b	2.50	b-g	28.47	fg
G_{11}	26.20	j	1.22	ghi	27.00	i
G_{12}	21.40	k	2.24	b-h	25.93	kl
G_{13}	21.30	k	1.81	c-i	26.03	k
G_{14}	65.80	de	2.96	bc	28.73	ef
G_{15}	74.10	c	3.14	b	30.47	b
G_{16}	71.50	c	2.57	b-f	29.37	cd
G_{17}	57.90	gh	1.02	hi	26.57	j
G_{18}	62.80	def	1.19	hi	26.03	k
G_{19}	73.70	c	2.04	b-h	28.87	ef
G_{20}	58.40	g	0.64	i	25.57	l
G_{21}	34.90	i	1.81	c-i	27.87	h
G_{22}	66.80	d	1.40	f-i	27.13	i
$LSD_{(0.01)}$	**3.9**		**1.291**		**0.4103**	
Significant level	**		**		**	
CV%	**4.2**		**17.97**		**0.88**	

** Significant at 1% level

Germplasms: G_1= ACI Summer king (check); G_2= BINA tomato 2 (check); G_3= BINA tomato 3 (check); G_4= AVTO-09809; G_5= AVTO-1007; G_6= AVTO- 1009; G_7= AVTO-1002; G_8= AVTO-201; G_9= BARI-11 (Jhumka); G_{10}= Laksi; G_{11}= JP-13; G_{12}= JP-26; G_{13}= JP-27; G_{14}= Sweeden-2; G_{15}= Netherlands-13; G_{16}= Sweeden-5; G_{17}= Apple Netherlands; G_{18}= SAU san-001; G_{19}= MAL-3; G_{20}= Purple-4; G_{21}= CSN-1 and G_{22}= Orange- 4.

CHAPTER V
SUMMARY AND CONCLUSION

5.1 SUMMARY

A field experiment was carried out during Kharif season of May 2015 to August 2015, at Horticulture Farm of Sher-e-Bangla Agricultural University (SAU) in the Madhupur Tract (AEZ 28, Paleaustult) of Bangladesh with an objective to study morpho-physiological behaviour of twenty two summer tomato germplasm under polyshed condition. A summary of methodology and results of this study is given below.

The soil of the experimental field initially had a pH of 6.9, organic carbon 1.05%, total N 0.08%, available P 12.78 ppm, exchangeable K 43.29 ppm, available S 23.74 ppm, available B 0.36 ppm. The experiment was designed with 22 treatments, laid out in a randomized complete block design (RCBD) with three replications. Each plot size was 3 m x 1 m.

The seeds were sown in 5^{th} May to get seedlings of 25 days old at the time of transplanting. All recommended cultural practices were followed to grow the crop. Frequent samplings were done at harvest for counting plant height, number of leaves plant^{-1}, number of branches plant^{-1}. The crop was harvested at maturity. All the data were statistically analyzed by MSTAT-C program and the differences between treatments means were evaluated by least significant difference (LSD).

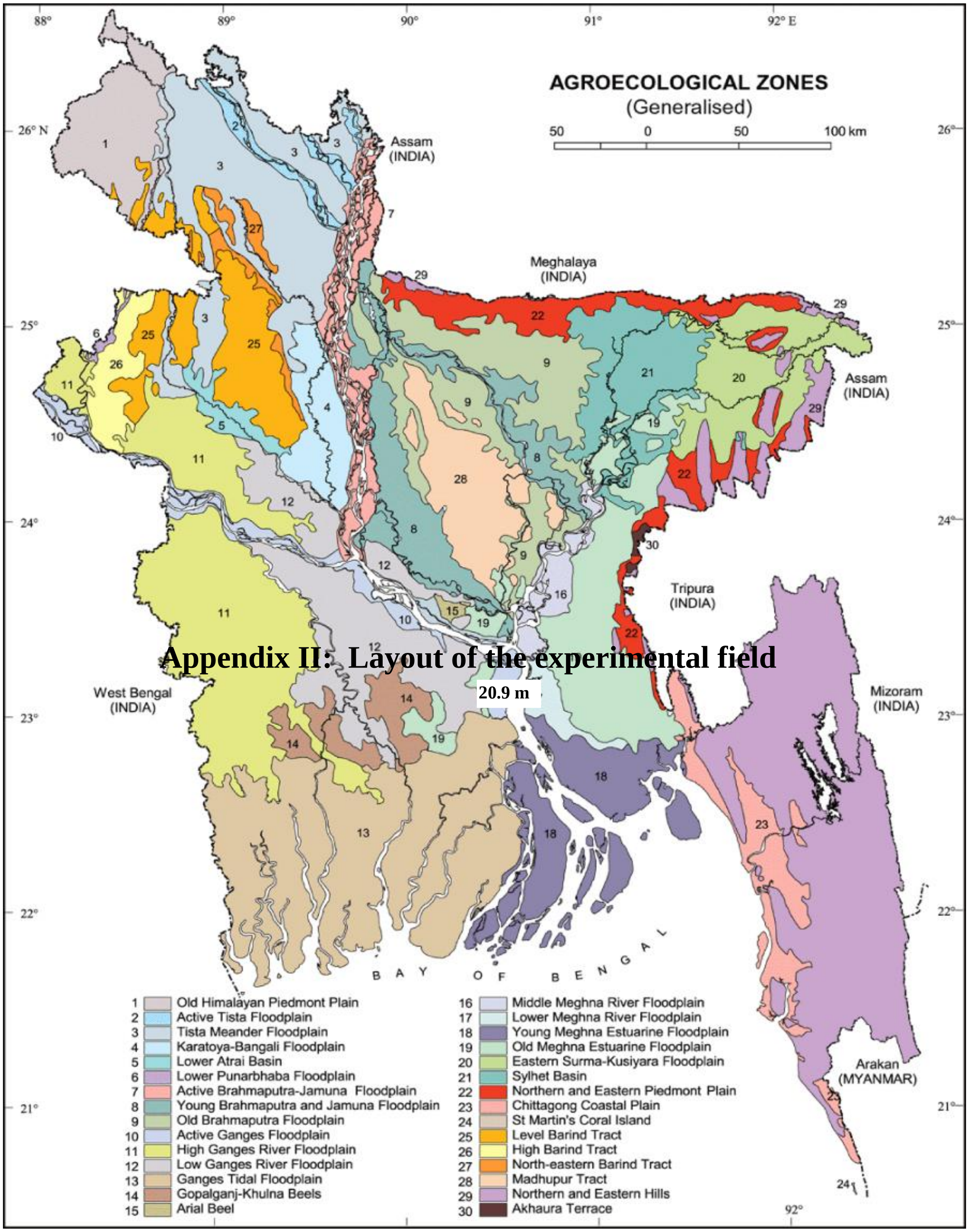
The result of the experiments revealed that the tallest plant was found in the germplasm JP-27 (191.2 cm) and the shortest plant was from that of CSN-1 (32.97m). Maximum number of leaves and branches $plant^{-1}$ were found from the germplasm of AVTO-09809 (60.20 and 26.0 respectively) whereas minimum number of leaves $plant^{-1}$ from that of CSN-1(22.13) and minimum number of branches $plant^{-1}$ was found from that of Apple Netherlands (5.333). The highest chlorophyll content (73.2 %) on leaves was observed from the germplasm of JP-26 whereas lowest chlorophyll content (31.4 %) on leaves was observed from the germplasm of JP-27. Longest period (31.3 days) was required for first flowering from AVTO-1002 whereas shortest period (19.3 days) from SAU san-001. The maximum number of flowers $plant^{-1}$ (64.0) was recorded from the germplasm of AVTO-09809 and the minimum (20.3) from the germplasm of Apple Netherlands. AVTO-09809 germplasm gave the highest number of fruits $plant^{-1}$ (40.0) whereas Purple-4 germplasm gave the minimum number of fruits $plant^{-1}$ (5.333). Among the germplasm of summer tomato Apple Netherlands (43.1 cm) gave the longest fruit length while JP-27 (21.4 cm) gave the shortest fruit length. Maximum fruit diameter (13.5 mm) was found from the germplasm of JP-13 which was statistically identical with Sweeden-5 (12.8 mm) germplasm and minimum fruit diameter (5.2mm) was found from BINA tomato-2. The highest single fruit weight (100.7 g) and yield $plant^{-1}$ (4.67 kg) were observed from the germplasm of AVTO-09809 and lowest single fruit weight (21.3g) was found from JP-27 germplasm. Maximum yield ha^{-1} (35.73 ton) was found from the germplasm of AVTO- 09809 and minimum yield $plant^{-1}$ (0.64 kg) and yield ha^{-1} (25.57 ton) was found from Purple-4 germplasm.

5.2 CONCLUSION

Summer tomato still, is very poorly present in our field; due to the traditional habits of the user and farmer cultivate to grow tomato germplasm with large fruit and the lack of available information on summer tomato cultivation. There is a big opportunity for summer tomato production. In this experiment G_4 (AVTO-09809) was found to be the best germplasm for summer tomato production. Such studies should be conducted to trial again.

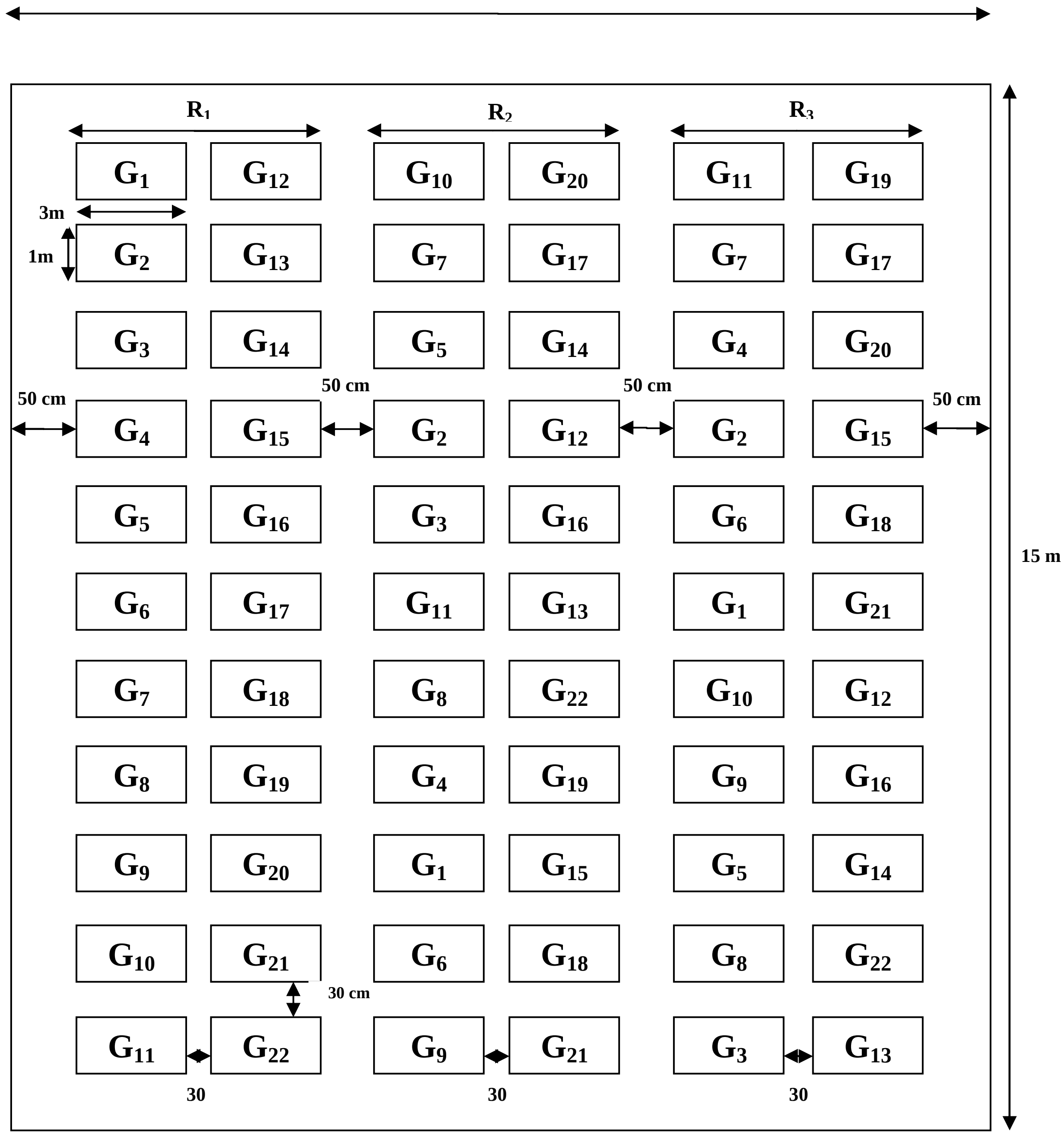
APPENDICES

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

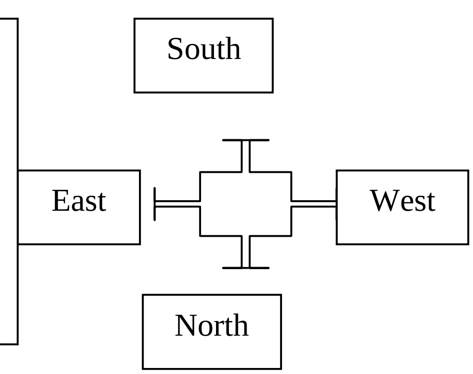


Appendix II: Layout of the experimental field

20.9 m



Variety: G_1= ACI Summer king (check); G_2= BINA tomato 2 (check); G_3= BINA tomato 3 (check); G_4= AVTO-09809; G_5= AVTO-1007; G_6= AVTO- 1009; G_7= AVTO-1002; G_8= AVTO-201; G_9= BARI-11 (Jhumka); G_{10}= Laksi; G_{11}= JP-13; G_{12}= JP-26; G_{13}= JP-27; G_{14}= Sweeden-2; G_{15}= Netherlands-13; G_{16}= Sweeden-5; G_{17}= Apple Netherlands; G_{18}= SAU san-001; G_{19}= MAL-3; G_{20}= Purple-4; G_{21}= CSN-1 and G_{22}= Orange- 4.



Appendix III: Analysis of variance of the data on plant height (cm), number of leaves plant^{-1} and number of branches plant^{-1} of different tomato varieties

Source of Variation	Degrees of Freedom (df)	Mean Square Values		
		Plant height (cm)	No. of leaves plant^{-1}	No. of branches plant^{-1}
Replication	2	20.326	0.750	7.106
Factor A	21	5833.999**	323.882**	75.045**
Error	42	9.724	5.860	5.868

** Significant at 1% level

Appendix IV: Analysis of variance of the data on chlorophyll content (%), days to first flowering and number of flowers plant^{-1} of different tomato varieties

Source of Variation	Degrees of Freedom (df)	Mean Square Values		
		Chlorophyll content (%)	Days to first flowering	No. of flowers plant^{-1}
Replication	2	17.515	1.652	18.124
Factor A	21	365.541**	28.783**	289.819**
Error	42	11.777	0.778	7.783

** Significant at 1% level

Appendix V: Analysis of variance of the data on number of fruits plant^{-1}, fruit length (cm) and fruit diameter (mm) of different tomato varieties

Source of Variation	Degrees of Freedom (df)	Mean Square Values		
		Number of fruits plant^{-1}	Fruit length (cm)	Fruit diameter (mm)
Replication	2	35.636	1.150	0.867
Factor A	21	168.219**	15.501**	85.182**
Error	42	10.747	0.442	1.323

** Significant at 1% level

Appendix VI: Analysis of variance of the data on single fruit weight (g), yield plant^{-1} (kg) and yield ha^{-1} (ton) of different tomato varieties

Source of Variation	Degrees of Freedom (df)	Mean Square Values		
		Single fruit weight (g)	Yield plant^{-1} (kg)	Yield ha^{-1}(ton)
Replication	2	21.197	1.037	0.003
Factor A	21	1384.295**	2.458**	13.852**
Error	42	5.690	0.614	0.063

** Significant at 1% level

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LIST OF ABBREVIATIONS

AEZ	=	Agro Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BAU	=	Bangladesh Agricultural University
BBS	=	Bangladesh Bureau of Statistics
cv.	=	Cultivar (s)
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
EC	=	Emulsifiable Concentrate
et al.	=	And Others
FAO	=	Food and Agriculture Organization of the United Nations
IRRI	=	International Rice Research Institute
LSD	=	Least Significant Difference
MoP		Muriate of Potash
ppm	=	Parts per million
RCBD	=	Randomized Complete Block Design