EFFECT OF HORMONE ON HEAT TOLERANT TOMATO HYBRID (*Lycopersicon esculentum* Mill.) LINES

MD. HARUNUR RASHID

DEPARTMENT OF HORTICULTURE &
POSTHARVEST TECHNOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

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BY

MD. HARUNUR RASHID

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Approved by :

....
(Dr. Shahabuddin Ahmad)
Supervisor

....
(Dr. Md. Nazrul Islam)
Co-supervisor

....
(Dr.Md. Nazrul Islam)
Chairman
Examination Committee

DEDICATED

TO

MY BELOVED

PARENTS

DECLARATION

This is to certify that thesis entitled, " **Effect of hormone on heat tolerant tomato hybrid (*Lycopersicon esculentum* Mill.) lines**". Submitted to Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of Master of Science in **Horticulture** embodies the result of a piece of bonafide research work carried out by **Md. Harunur Rashid, Registration No- 00210/24772** under my supervision and guidance. No part of the thesis has been submitted for any other degree in any other institutes.

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

Date:December,2005

Dhaka, Bangladesh

....

(Dr. Shahabuddin Ahmad)

Senior Scientific Officer, HRC,

BARI, Joydebpur, Gazipur

Supervisor

Some commonly used abbreviation

Full Word	Abbreviation
Bangladesh Agricultural Research Institute	BARI
Horticulture Research Centre	HRC
North	N
Centimeter	cm
And others (at elli)	*et al.*
Degree Celsius (Centigrade)	°C
Degree Fahrenheit	°F
Hectare	ha
Gramme	g
Hydrogen ion conc.	p^H
Kilogram	kg
Least significant difference	LSD
Meter	m
Standard error	SE
Ton (1000 kg)	t
East	E
Coefficient of variance	CV
Duncan's Multiple Range Test	DMRT
Degrees of freedom	df

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ABSTRACT

Tomato is one of the popular vegetables in Bangladesh. High temperature (both day and night), humidity, rainfall and light intensity are the basic limiting factors of the tomato production in summer season. During summer season tomato is available in urban market at an exorbitant price. These tomatoes are coming from exotic source mostly through unapproved channel. There is a great demand of tomato in summer- rainy season but there is no good variety for this season. Recently BARI has released some heat tolerant open pollinated and hybrid varieties with some limitations liking hormone application and smaller fruit size. Considering the factors, the experiment was under taken to evaluate the newly developed 13 heat tolerant tomato hybrids under field condition with and without application of hormone during summer-rainy season. The experiment was conducted at the Research Farm of Olericulture division under Horticulture Research Centre of Bangladesh Agricultural Research Institute (BARI) Joybebpur, Gazipur during the month of May 2004 to August 2004. The experiment was laid out in a RCBD (factorial) with three replications. Thirteen (13) hybrids of heat tolerant tomato lines and with and without hormonal application were included in this experiment. The highest yield of fruit per plant (587.50 g) was recorded from the line C_{12} and the lowest yield of fruit per plant (221.50 g) was found from the line C_3. Hormone application had positive effect on the yield contributing characters and yield of hybrid tomato lines. The highest yield of fruits per plant (444.72 g) was recorded from the hormone-applied line, which was 65 % higher than no-hormone. Heat tolerant hybrid tomato line C_{12} with the hormone application resulted better yield contributing characters and produced highest yield of fruit per plant (778g).

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CHAPTER 1

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the popular vegetables in Bangladesh. It is a self-pollinated crop under the family Solanaceae. All the cultivated types of tomato belong to *Lycopersicon esculentum* and are generally accepted to have originated in new world (The America) i.e. the Andean region composed of parts of Bolivia, Chile, Colombia, Ecuador and Peru. Evidence from the diversity of cultivated type, culinary uses and from the abundance of native names of the tomato fruits, all suggested that tomato was originally domesticated in Mexico (Jenkins, 1948). Soon after discovery of the new world, tomato was taken to Europe and then gradually it was spreaded throughout the rest of the world (Heiser, 1969). At present, tomato is a universally known vegetable and is one of the widest grown vegetables in the world. It is the largest vegetable crop after potato and sweet potato in the third world countries (Rashid, 1993). Tomato is popular for its diversified use like salad, stewed, juices, sauce and pickles and preserved. Tomato is highly nutritious as it contains 1.90 g protein, 320 IU vitamin A, 1.8 mg iron, 31mg vitamin C per 100g edible portion (Rashid, 1993).

Because of its nutritive value and diverse use both in fresh and processed form tomato has become the most valuable vegetable in Bangladesh. Total production continues to rise all over the world and also in Bangladesh. Its harvesting is mostly confined to the month of January, February and March. Tomato can grow under a wide range of climatic conditions, but they are extremely sensitive to heat and wet growing conditions, limiting its adaptation in humid tropics, which prevails, in the summer rainy season of Bangladesh. Tomato cultivation during March to September in Bangladesh is constrained due to the adverse weather of summer along - with absence of heat tolerant varieties. Tomato requires day temperature of 21°-28°C and moderately cools night temperature of 15°-20°C for proper fruit setting (Tindall and Williams, 1977). High temperature (both day and night), humidity, rainfall and light intensity are the basic limiting factors of tomato production (Abdullah and Verkerk, 1968). High day and night temperature above 32°C and 21°C respectively, was reported as limiting factor to fruit-set due to an impaired complex of physiological process in the pistil, which results in floral or fruit abscission (Picken, 1984). According to Villareal and Lai (1979) and Villareal *et al.* (1978) heat tolerance in tomato is defined as "The ability to set fruit under night temperature not lower than 21°C".

Due to its favorable growing conditions and high demand there are many varieties for winter season, developed by BARI and introduced from abroad. But limited efforts have been given so far to overcome the high temperature barrier preventing fruit set in summer-rainy (hot-humid) season. Presently demand has been created among farmers for summer – rainy season variety. Very recently BARI has strengthened the programme for year-round tomato variety development and already succeeded to develop some heat tolerant open pollinated variety and F_1 tomato varieties (Anon; 1998) with some limitations like hormonal application or smaller fruit size. However, very limited research was done to improve yield and quality of tomato varieties.

In Bangladesh condition, tomato is available in urban market at an exorbitant price (TK. 40 to 60/Kg) in summer season. These tomatoes are coming from exotic sources mostly through unapproved channel. There is a great demand of tomato in summer- rainy season. But there is no good variety for the season. There are reports that the heat tolerant varieties fruit setting can be improved by using plant growth regulator "Tomatotone" (AVRDC 1990).

Therefore the experiment was conducted with the following objectives-

i) To observe the yield potential of hybrid lines developed by BARI in summer-rainy season under field condition.

ii) To determine the performance of heat tolerant hybrid lines with hormonal application and

iii) Finally to identify lines which can be grown in summer-rainy season under field condition with or without hormone application.

CHAPTER 2

REVIEW OF LITERATURE

In Bangladesh, we get various types of vegetables all the year round. Among these types of vegetables tomato (*Lycopersicon esculentum* Mill.) is one of the major vegetables in Bangladesh. The crop is a relatively cool temperature-loving crop, hence, grown in temperate countries and in the dry winter months of tropical countries. It is extremely sensitive to hot -humid conditions. Very little effort has been given in other part of the world to develop varieties adaptable to the tropics. Such effort is even meager in Bangladesh. Information available in the literature pertaining to the evaluation of hybrids for yield, floral and fruit characters with regards to tolerance to high temperature stress are reviewed and presented in this chapter.

2.1 Effect of hormone application on summer tomato production

No significant difference was observed between summer lines TM 111 and TM 367 in the entire yield parameters studied TM 111 produced 19.6 t/ha with tomatotone application under polytunnel while TM 367 yielded 20.5 t/ha under similar condition (AVRDC,1997).

Time required for fruit set, fruit maturity, mean fruit weight, and fruit yield / plant were affected by different tomatotone concentrations. Both fruit set and maturity were earlier at 2% concentration (AVRDC,1997)

When tomatoes are grown under unfavorable conditions, such as during summer in tropical countries, the usual problem is low fruit set. The problem is due to high night temperatures (above 22°C) and high humidity, which result in poor pollination and flower fertilization. Although the problem is solved with the use of heat-tolerant varieties, these are inadequate under extreme conditions. Application of plant growth regulators has been shown to improve fruit setting, particularly in varieties that have low level of heat tolerance (AVRDC, 1990).

Synthetic plant growth regulators (PGRs) such as 4-chlorophenoxyacetic acid (CPA) now used commercially in Korea, Japan and China are known to influence fruit setting in tomato. These are applied at 50 mg/liter as a spray on flower cluster when they are in bloom. Spraying is usually done on each cluster at 7- to 14 – day intervals. It is claimed that the treatment increases fruit set and fruit size and induces early yields. However, it may cause puffy fruits at high concentrations or under high temperatures (AVRDC,1990).

Tomato (*Lycopersicon esculentum* Mill.) is seldom grown in summer in Bangladesh, because of high temperatures, high humidity and heavy rainfall. An attempt was made in 1991 to grow a summer tomato crop by growing tomatoes on raised beds, using heat-tolerant lines, chemical application for improving fruit set and using wild species as root stock to control diseases. Tomatoes transplanted in June on raised beds gave an excellent crop stand and growth compared to transplanting onto flat plots. Two lines, TM 0111 and TM 0367, from the Asian Vegetable Research and Development Center (AVRDC) set some fruit in summer, but further fruit set increase were obtained by use of the plant growth regulator "Tomatotone." Plants sprayed at flowering stage with 2% Tomatotone resulted in an average 760-940 g Parthenocarpic fruits / plant (AVRDC,1990).

2.2 Effect of heat tolerance on summer tomato production

Goreta *et al.* (2000) conducted field experiments with five determinate tomato hybrid cultivars (Balca, Sultan, Reword, Dublet and Serdika) were carried out at two locations (Imotski and Trogir) in 1996 and 1998. Average fruit weight in all cultivars was higher from summer planting.

Florido *et al.* (1999) found plantlets (21-days-old) of Nagcarlang and Campbell 28, tomato cultivars differing in heat tolerance. The best temperature (40°C) and method were then selected in order to screen 20 germplasm accessions, Nagcarlang, Mex-12, P1410 and L10-3 were the most heat tolerant on this basis, and are recommended for use in breeding programmes.

Rahman *et al* (1998) reported that the effects of temperature and water stress on agronomic and physiological characteristics were studied in heat tolerant tomato cultivars TM 0126. Plants were grown in a phytotron at day/night temperature of $23/18^0$ (moderate temperature regim, MT) or $30/25^0$ (high temperature regime, HT). HT significantly reduced yield, pollen germination percentage, shoot and root DW.

Pereira and Reisser (1998) found in a trial in Pelotas, Rio Grande do Sul, Brazil, the hybrid tomato Empire was sown in a plastic greenhouse on 15 or 30 December 1994 and 16 January 1995. The earliest sowing date resulted in the highest yield (113.9 t/ha) and the highest total yield (163.0 t/ha).

Baki and Stomuel (1995) found that under optimum temperature, fruit set ranged from 41% to 84% and from 45% to 91% in the heat-sensitive and heat-tolerant genotypes, respectively. Under high temperature, no fruit set in the most heat-sensitive genotypes. Fruit set in the heat-tolerant genotypes ranged from 45% to 65%. The response of pollen to heat was genotype dependent and not a general predictor of fruit set under high temperature stress.

Scott *et al.* (1995) reported that Equinox, a determinate, heat-tolerant, fresh-market tomato hybrid that sets a high percentage of marketable fruit in spring and autumn in Florida. Under 30-33°C/21-25°C day/night temperatures, fruit set is superior to that of most large-fruited cultivars, but flowers abort in the early trusses.

Hanna *et al.* (1994) reported that studies were conducted in 1992 and 1993 under optimal and sub-optimal field temperatures for fruit set of some heat-tolerant and less heat-tolerant tomato cultivars. Sub-optimal temperatures during fruit set reduced the yield of all tomato cultivars, but yield reduction was less in heat-tolerant cultivars. At minimum/maximum temperatures above 73/95°F, the heat-tolerant and less heat-tolerant cultivars produced very little yield.

Santipracha (1994) found in a trial of 8 varieties to identify heat-tolerant types suitable for commercial production in southern Thailand, all the varieties proved well adapted to the summer climate of Songkhla, but the highest yielding were 3-31A-B1-2B, S111 and B200 (about 12 – 14 tons /ha.)

Xu *et al.* (1994) found the new virus-resistant, heat-tolerant, high-yielding cultivar was released in the Henan province of China in 1991. Bred by crossing the early line 81-1-1 with the large-fruited, high-quality line 79-2-3, it gives large, good-quality fruit. This cultivar out yielded Henan 3 by 20.06% with summer cultivation.

Cheema *et al.* (1993) worked to extend the period of growing and availability of tomato in northwest India, a study was carried out in the field during 1989-90 to identify genotypes having extended fruit setting ability at high temperature (40/25°C day/night). 9 genotypes were rated as heat tolerant, having an average of 60-83% fruit set. Fruits weighed 20-40 g. Marketable yield was low (110-1040 g/plot) due to disease pressures.

Baki and Stomuel (1993) studied levels of heat tolerance in the genotypes of tomato by determining percent fruit set under the high temperature regimes. They found that, under optimum temperature ($27^0/23^0$C day/night), fruit set in the heat sensitive genotypes ranged from 41 to 84% and in the heat tolerant genotypes from 45 to 91%. Under high temperature $35^0/23^0$C day/night), no fruit set was observed in the heat sensitive genotypes, where as fruit set in the heat-tolerant genotypes ranged from 5 to 64%.

Baki and Stomuel (1993) conducted an experiment on heat tolerant tomato (L. *esculuntum* Mill.) breeding lines, 4 heat tolerant and 4 heat sensitive cultivars in the green house under high temperature (39^0C/day/28^0C night) and in the field. Under high temperature conditions, the heat tolerant lines, heat-tolerant cultivars and the heat sensitive cultivars produced respectively, the following per plant flowers, 168, 94 and 55; fruit set 70% 52% and 30%; yield 410, 173 and 11g; and normal mature fruit, 72%, 37% and 7%. High temperature induced flower abscission, reduced fruit set and yield, and increased the incidence of abnormalities.

Baki (1991) reported nine heat-tolerant tomato-breeding lines, four heat-tolerant cultivars, and four heat-sensitive cultivars were evaluated in the greenhouse under high temperature (39°C day/28°C night) and in the field in 1989. Under high-temperature conditions, the heat-tolerant lines, heat-tolerant cultivars and heat-sensitive cultivars produced, respectively, the following per plant: flowers, 186, 94 and 55; fruit set, 70%, 52% and 30%; yield, 410, 173 and 11 g; and normal mature fruit, 72%, 37% and 7%.

Dane *et al.* (1991) reported that Selected tomato genotypes were evaluated for fruit-setting ability under high-temperature field and greenhouse conditions. Most of the Asian Vegetable Research and Development Center (AVRDC) selections 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.

Hanna *et al.* (1991) found that LHT24 is primarily a source of heat-tolerant germplasm but can be used as a summer tomato for home garden production.

Hassan (1991) reported the stock plants of the determinate field tomato hybrid Elan, grown under plastic in summer, were trained with 1, 2 or 3 stems. Plants with 2 stems produced the greatest number of fruits, fruit weight and seed yield.

Dane *et al.* (1991) performed a field evaluation of selected genotypes of tomato for their fruit setting ability under high temperature condition. Diallel analysis indicated that pollen fertility and fruit set under high field temperatures were primarily under additive gene control.

Bodo (1991) stated that Pollen viability test was based on the idea that carmino acetic acid (CAA) effectively stains only the cytoplasm of intact cells with functioning membranes. Although, this technique does not evaluate the actual pollen germination, nonetheless, it gives an indication of apparent viability and is much in use (Carrol and Low, 1976; Marcade *et al.*, 1997 and Polowick and Sawhney, 1985).

AVRDC (1990) reported that Seven F1 hybrids obtained from heat-tolerant varieties and lines were evaluated in Thailand in 3 different seasons: cool (October-February), hot (March-July) and rainy (July-October). The local cv. Seeda gave the lowest yields, while the new, and heat tolerant varieties Seedathip I and Seedathip II yielded 3-4 times higher. All F1 hybrids with either of these 2 new varieties, as one of the parents, set more fruit than those with Seeda as a parent. Hybrids 111 (B1 X Seedathip II) and 115 (B2 X Seedathip II) were more acceptable to consumers because of their better color, larger fruits.

Rana and Kalloo (1989) evaluated 156 genotypes of tomato for number of flowers per cluster, percent fruit set, percent flower drop, number of fruits per truss, number of fruit per plant, size of fruit, yield/plant and stigma position in antheridial cone at high temperature (38-40^{0}C day and 20-25^{0}C night). Out of that 138 genotypes could not set even 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%.

Lin and Hong (1989) Selected among breeding lines from the Asian Vegetable Research and Development Center, this indeterminate F1 hybrid variety gives a mean fruit set of 84% for the autumn crop and 28% and 80-90% in lowland and highland areas, respectively, for the summer crop. The variety is heat tolerant, giving a good fruit set at high temperatures, and highly resistant to tomato mosaic virus.

Opena *et al.* (1989) stated that AVRDC scientist from planting during hot, wet summer season in Taiwan selects tropical breeding lines. During this period, daytime temperature (maximum) could go as high as 34^0 or so while night temperature would be not lower than 21^{0}C.

Berry and Uddin (1988) reported that high fruit set in this particular study was not associated with high seed number in the majority of tolerant cultivars evaluated.

Fruit set in tomato reportedly is interrupted at temperatures above 26/20^{0}C day/ night, respectively; and is often completely arrested above 38/27^{0}C day/night (El-Ahmadi and Stevens 1979a; Kuo *et al.*, 1978 and Stevens and Rudich, 1978). High temperature also causes many other impacts other than fruit set like fruit size and quality (Opena *et al.*, 1987a).

In a study, crosses among heat tolerant parent stocks were noted to have better fruit setting ability and yield than their crosses with heat sensitive parents (Opena *et al.*, 1993). However, it was apparent from the range of F1 means that some hybrids between heat tolerant and heat sensitive stocks could equal if not surpass, the performance of the hybrids among heat tolerant stocks, further supporting the result from the diallel experiment (Opena *et al.*, 1987b).

Shashi and Satyanarayana (1986) reported in a paper entitled "Breeding tomato for heat tolerance" that fruit yield during summer is hardly 100-150 g per plant, but in the crosses he made, the average yield ranged from 450g to 800g.

Bar-Tsur *et al.* (1985) reported that high temperature reduce the leaf photosynthesis. They also reported that high humidity and rainfall decreased the survival rate of tomato plant by encouraging wilt incidence.

High day (above 32°c) and night (above 21°c) temperature were reported as limiting fruit-set due to an impaired complex of physiological process in the pistil, which results in floral or fruit abscission (Picken, 1984).

In 1983, Dinar *et al.* stated that poor fruit set at high temperature in tomato due to callose formation in the leaf petiole and an inability of reproductive organs to import assimilates in the early stages of flower development.

Differences existed among the cultivars in their ability to transmit their fruit setting ability under high temperature to their immediate hybrid progenies. Hybrid progenies appeared to have better consistency of performance especially under less than optimal growing conditions (Yordanov, 1983).

Hanna *et al.* (1983) in a study on tomato flower structure and fruit set under heat growth and also under ideal temperature during growth reported that both traits are genetically controlled, with partial dominance for high expression.

Chen *et al.* (1982) reported that genotypic differences for their performance in the field were more related to their adaptability to high temperature. They concluded that, selection in a breeding program should be based on selecting those genotypes with higher heat adaptability rather than those with high pre-acclimation levels of heat hardiness, which was found to decline within a narrow temperature range and becomes less efficient at temperatures above 30^0C.

Hanna and Hernandez (1980) compared several characters related to heat tolerance in tomatoes in 5 varieties under summer and spring seasons. In summer, average minimum temperature was 24^0C and maximum was 34.3^0C. In spring, average minimum temperature was 15.3^0C and maximum was 25.1^0C. 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 1.2% in summer. BL6807 had less flower drop and highest percentage of stained pollen in summer.

Hanna and Hernandez (1979) tested 23 tomato lines and varieties under high day (above 32.3^0C) and night (above 23.9^0C) temperature conditions for fruit set, flower drop and blind fruit using the three base flowers on each of six clusters per plant. They found that BL6807 lad a mean fruit set of 48.5% and CL 9-0-0-1 (33.6%) whereas, L401 had 1.2% only. The heat tolerant lines have small fruits except CL 9-0-0-1, which was larger.

Kuo *et al.* (1978) stated that High light intensity affects the internal temperature of the reproductive organ of tomato.

Shelby *et al.* (1978) compared two heat tolerant tomato (*Lycopersicon* *esculentum* Mill.) breeding lines AV165 and Nagcarlang, with the heat sensitive 'Floradel' in fruit set, pollen abortion and embryo sac abortion. They found that the two heat tolerant cultivers had a significantly 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. High temperature is known to limit fruit-set of tomato due to simultaneously and / or sequentially impaired series of reproductive processes i.e. Pollen production and development, ovule development, pollination, germination of pollen grains, pollen tube growth, fertilization and fruit initiation (Rudich *et al.*, 1977 and Stevens, 1979).

The poor fruit-set at high temperature in the tomato, principally, might be a result of a reduction of carbon export from the leaf (Dinar *et al.*, 1982 and Ho, 1979).

Levy *et al.* (1978) claimed that reduced fruit set at high temperatures is attributed to flower drop (Abdullahh and Verkerk, 1968; Iwahori, 1965; Sugiyama *et al.*, 1966 and Charles and Harris, 1972). Increased flower abscission was observed at the time of flower dehiscence (Johanson and Hall, 1953), which was a result of the failure of fruit set rather than direct effect of high temperature.

Heat tolerance is often characterized by sustained pollen viability and favored anther dehiscence (El-Ahmadi and Stevens, 1979a; Rick and Dempsey, 1969; Rudich *et al.*, 1977). However, for certain genotypes fruit set does not appear to depend on reduced pollen germination or fertilization at high temperatures (Charles and Harris, 1972). This implies the involvement of Parthenocarpic fruit set in the improvement of heat tolerance (El-Ahmadi and Stevens, 1979b; Stevens and Rudich, 1978).

High temperature drastically reduces the fruit setting ability of tomatoes (Abdullah and Verkerk, 1968, Charles and Harris, 1972; El-Ahmadi and Stevens, 1979a; Kuo *et al.,* 1978 and Rudich *et al.,* 1977). The tomato improvement programme at AVRDC accorded high priority to the incorporation of genes for heat tolerance to tropical lines (Opena, 1985 and Villereal *et al.*, 1978).

Temperature determines the fruit size in various crops (Rylski, 1973). At night temperature of 14^0C Went (1957) obtained tomato fruit three times the size as obtained at 26^0C.

Flower buds at 5 to 9 days before anthesis and 1 to 3 days after anthesis were highly sensitive to high temperature (Iwahori *et al.*, 1963). Both macro-and microspore mother cells at meiosis and 9 to 8 days before anthesis were especially sensitive to high temperature (Iwahori, 1965). El-Ahmadi and Stevens (1979a) also observed reduction in pollen viability and anther dehiscence when flowers were exposed to 40^0C for 4 hours. Optimum temperature for pollen germination was found to be near 27^0C (Abdullahh and Verkerk, 1968). At high temperatures, pollen germination and pollen tube growth were retarded (Abdullahh and Verkerk, 1968; Charles and Harris, 1972).

Abdullah and Verkerk (1968) reported that high temperature (both day and night), rainfall, humidity, and light intensity are the basic limiting factors of tomato production.

Abdullahh and Verkerk (1968) reported that high temperature (both day and night) rainfall; humidity and light intensity are the basic limiting factors of tomato production.Less than 1% (38 of 4050 accessions) of the world collection of the garden tomato (*Lycopersicon esculentum* Mill.) and related *lycopersicon* species displayed a high level of heat tolerance based on fruit setting ability at high temperature.Villareal *et al.*, (1978).

Jwahori (1967) stated that high temperature increased the probability of floral abscission after anthesis in tomato.High night temperature reduced the tomato flower size with small anthesis and abortive pollens, as well as auxin content (Saito and Ito, 1967.

The number and viability of pollen grains are important for successful fertilization (Abdullah and Verkerk, 1968). Pollen is formed from tetrads seven days before anthesis and reaches maturity within four days (Sugiyama *et al.,* 1966). Reduced pollen production was caused by low assimilate supply (Howlett, 1936), high temperature (40^0C) at meiosis stage (Iwahori, 1965) or low temperature (10^0C) (Charles and Harris, 1972). However, reductions in pollen production and viability (Abdullah and Verkerk, 1968), and pollen germination and pollen tube growth in the style (Iwahori and Tokalashi, 1964; Iwahori., 1967) are mainly caused by heat damage.

CHAPTER 3

MATERIALS AND METHODS

The materials used and methodology followed during the experiment are presented in this chapter. A brief description of experimental site, plant materials, plant growth regulator, experimental treatment, climate and weather, manures and fertilizers, experimental design and layout, growing of plants, intercultural operation, data collection and statistical analysis are included under the following heads:

3.1 Experimental site

The field experiment was carried on at the Horticultural farm of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh during the month of May 2004 to August 2004.

3.1.1 Location

The location of the site is at 24-00^{0}N Latitude and 90.25^{0}E Longitude at an elevation of 8.4 meters from the sea level (Anon., 1995).

3.1.2 Soil

The soil of the experimental field was sandy clay loam in texture having a pH around 6.0. The soil belongs to the Chita soil series of red brown terrace (Anon., 1988; Brammer, 1971 and Shaheed, 1984). The soil for vegetable research was later developed by riverbed silt

3.2 Materials of the experiment

3.2.1 Plant materials

Thirteen (13) hybrids of tomato, mostly with different degrees of heat tolerance made by the Olericulture Division of HRC, Bangladesh Agricultural Research Institute (BARI).The collected materials were grown in summer-rainy season during 2004 for the study. The thirteen heat tolerant hybrids were C_1 (1 X 1), C_2 (1 X 3), C_3 (1 X 4), C_4 (1 X 6), C_5 (3 X 3), C_6 (3 X 7), C_7 (2 X 1), C_8 (2 X 3), C_9 (2 X 5), C_{10} (2 X 6), C_{11} (4 X 4), C_{12} (4 X 8) and C_{13} (5 X 5).

3.2.2 Plant growth regulator

Half of the plant population in each unit plot was sprayed with 2% "Tomatotone" (a fruit setting hormone) in two times at 7 days interval.

3.3 Climate and weather

The experimental site is situated on the sub-tropical climatic zone and characterized by heavy rainfall during the months of May to August and scanty rainfall during the rest of the year. The average minimum and maximum temperature during the crop period was 24.35^{0}C and 34.03^{0}C respectively. The mean minimum and maximum relative humidity was 77.58% and 91.65% respectively. The weather data (air temperature and humidity) during the study period are presented in Appendix 1.

3.4 Growing of plants

Seeds of the thirteen collected hybrids were sown densely in the primary seedbed. Nine days after sowing, the young seedlings at the cotyledonary stage were transplanted in the secondary seedbed at a spacing of 5 cm x 5 cm. The sowing was done on 20 May, 2004. The seedlings were transplanted in the main experimental field on 13 June, 2004. Plants were given support after transplanting in the main field by bamboo sticks. The crop was grown under transparent and non-ultraviolet resistant polytunnel.

3.5 Experimental design and layout

The experiment was set up in a Randomized Complete Block Design (RCBD) with three replications. Thirteen (13) hybrids of tomato were considered as Thirteen (13) genotypes for the experiment. The Genotypes were randomly set in each block. The unit plot size was 2.8 m x 1.0 m and the plants were spaced 60 cm x 40 cm on beds. Each unit plot contains double rows accommodating 14 plants. Half of the plant populations in each unit plot were sprayed with 2% "tomatotone", a fruit setting hormone. A mini hand sprayer only to the blooming flower cluster sprayed the hormone. Data were collected from randomly selected 5 plants in sprayed and unsprayed plant separately. The polytunnels for the crop were 2.3 meter wide having two 1.0-meter wide beds with 30 cm drain in-between which served as irrigation channel.

3.6 Manures and fertilizers application

Ten metric tons of cow dung as an organic matter and chemical fertilizers @ of 450 kg urea, 250 kg TSP and 150 kg MP per hectare were applied. During final land preparation, half of the cow dung and the entire amount of TSP were applied. The pits were prepared one week before planting. The remaining cow dung and $^1/_3$ of MP were applied at that time. The entire urea and rest $^2/_3$ of MP was given in 3 equal installments at 10, 25 and 40 days after transplanting by top dressing.

3.7 Intercultural operation

Weeding and mulching were done followed by top-dressing and irrigation at 15 days interval.

3.8 Data collection

Data were collected from 5 randomly selected sprayed and unsprayed plants on the following parameters in each unit plot.

- **Days to 50% flowering:** It was estimated as the number of days required from sowing to first flower opening of the 50% plants of each replication.
- **Flowers per cluster:** Flowers of each cluster starting from 1 to 5 clusters were counted in every plant of the selected 5 plants and their average was taken as number of flower per cluster.
- **Fruits per cluster:** The average value of total number of fruits in the fruited clusters was counted and was taken as fruits per cluster.

- **Fruit set (%):** The value was calculated by using the following formula –

$$\text{Fruit set\%} = \frac{\text{Total number of fruits of } 1^{st} \text{ five clusters}}{\text{Total number of flowers of } 1^{st} \text{ five clusters}} \times 100$$

- **Fruits per plant:** The average value of the total number of fruits per plant harvested at different dates from the 5 selected plants was counted and taken as fruits per plant.

- **Individual fruit weight (g):** Based on the ten representative fruits individual fruit weight in gram was calculated.

- **Yield per plant (Kg):** Fruit yield of 5 plants from each plot was recorded and yield per plant was calculated.

- **Fruit length (cm):** Fruit length was measured from the neck of the fruit to the bottom of the same by using a digital slide calipers average of 10 representative fruits from each of the plot was recorded.

- **Fruit diameter (cm):** Fruit diameter was measured along the equatorial part of the same 10 representative fruits taken for fruit length by digital slide calipers and their average was taken as the diameter of the fruit.

- **Branches per plant:** At final harvesting stage, all the primary branches were counted in each of the selected 5 plants and their average value was taken as number of branch per plant.

- **Plant height (cm):** Plant height was measured from the soil surface to the tip of the tallest branch at final harvest and the value was the average of 5 plants.

- **Brix (%):** A hand refractrometer was used to record the percent of brix. The value was the average of five representative fully ripened fruits.

- **Viable pollen grain (%):** Dusting of the pollen grains from the anther cone was done on a glass slide. Carmine Acetic Acid (CAA) solution (single drop) was used to stain the specimen and was covered with a cover slip. Pollen grains were viewed under a light microscope. The pollen grains which were normal and properly stained were considered as viable while those were not well stained or wrinkled were considered as non-viable.

Plate 1. Experimental field view under a polythene tunnel in summer season

Plate 2. Hormone application on the flower cluster of tomato hybrid lines.

Plate 3. Fruited tomato plants of different hybrid lines

3.9 Statistical analysis

MSTAT-C program was used to analyze the data statistically. The recorded data for different characters were subjected to variance analysis. Genotypes means were compared by Duncan's Multiple Range Test (DMRT) and coefficient of variation (CV %) were also estimated as suggested by Gomez and Gomez (1984).

CHAPTER 4

RESULTS AND DISCUSSION

The results obtained from the present study in respect of different parameters recorded are presented in 12 tables in total starting from 4.1.1 to 4.3.4. The summaries of analysis of variance for different parameters are presented in appendix 2. Results are discussed chronologically below:

4.1 Effect of tomato hybrid lines

Plant height

Plant height of thirteen hybrids of tomato under field condition at final harvest stage showed significant differences (Table 4.1.1), plant height ranged from 86.58cm to 114.52cm. The genotype C_6 showed the tallest plant height (114.52 cm) which was statistically similar to that of C_8 and C_{13} showed the shortest (86.58cm) plant height. The hybrids C_2, C_4 & C_{10} were closely related to the C_6 & C_8. It was revealed that most of the hybrids of tomato performed better under field condition in Bangladesh. Phookan *et al.* (1990) also reported a variation in plant height ranged from 46.00 cm to 95.00 cm in an experiment of 29 hybrids of tomato when grown under plastic house condition in summer.

Number of Branches

The number of branches per plant differed significantly among the hybrids of tomato at final harvest stage (Table 4.1.1). The number of branches per plant varied from 2.95 to 7.60. The hybrids C_5 showed the highest (7.60) number per plant, which was significantly different from the remaining hybrids but it, was statistically similar to that of C_1 (7.00). The lowest branching was observed in the hybrid C_7 which was statistically similar to other hybrids except C_1, C_2 andC_5. Phookan *et al.* (1990) found that the number of branches per plant varied from 5.00 to 10.50 in summer season under plastic house condition. Results was little bit lower to this finding, which might be due to the difference of growing environments or the difference of hybrids or both.

Table 4.1.1. Branch per plant and plant height of 13 tomato hybrid lines

Hybrids	No. of Branches / Plant	Plant height (cm) at last harvest
C_1	7.00 **a**	101.43 **b-d**
C_2	5.28 **b**	108.78 **ab**
C_3	3.13 **f-h**	90.22 **ef**
C_4	3.20 **fg**	107.70 **ab**
C_5	7.60 **a**	97.87 **de**
C_6	4.47 **c**	114.52 **a**
C_7	2.52 **h**	93.08 **d-f**
C_8	3.52 **e-g**	113.68 **a**
C_9	3.52 **e-g**	93.93 **d-f**
C_{10}	4.00 **c-e**	106.47 **a-c**
C_{11}	3.77 **d-f**	94.57 **d-f**
C_{12}	4.40 **cd**	98.78 **cd**
C_{13}	2.95 **gh**	86.58 **f**
CV%	**12.49**	**6.37**

In a column, means followed by common letters under the same factor are not significantly different at 1% level by DMRT. 'C' stands for cross or combination or hybrid line

Days to 50% flowering

Days required to 50% flowering were recorded under field conditions of thirteen hybrids of tomato. All the hybrids varied from 41 days to 49 days (Table 4.1.2). The minimum days were required by the genotype C_4 (41 days) that was statistically similar to that of C_5 and C_{10}. The maximum days were required by the genotype C_9 (48 days). Besides this all other hybrids showed statistically similar results. 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.

Flower per cluster

Significant variation was observed among the hybrids in terms of number of flowers per cluster (Table 4.1.2). Maximum flowers per cluster (8.11) were produced by the hybrids, which were statistically similar to C_{10}, C_{12}, C_{13} (7.87) and followed by other hybrids. The minimum flower per cluster was produced by the hybrid C_2 (5.07). The number of flower per cluster is an important character, which has got the significant role to determine the yield of tomato fruit. The production of flowers per cluster may be affected by the cultivars and temperature. Aung (1976) and stevens (1979) reported that an extent of decreased flower number depends on cultivars. The finding supported to the variation among the hybrids in the present investigation.

Viable pollen grain (%)

Percent viable pollen grain varied significantly among the thirteen hybrids of tomato (Table 4.1.2). The highest viable pollen grain was produced by the hybrid c_4 (64.33%), which was statistically similar to the hybrids C_{10} (62.63%) and c_7 (59.07%). The remaining hybrids except C_{11} (48.40%) and C_5 (39.00%) produced statistically similar viable pollen. This indicated that some of the hybrids have the capability to produce high percent of viable pollen grain as per carminoacetic acid viability test. It gives an apparent indication of pollen viability. (Bodo, 1991).

Fruit set (%)

Diversity was observed among the hybrids percent fruit set (Appendix 3). Percent fruit set varied from 43.22 to 24.17 (Figure 1). The highest fruit was set by C_{10} (43.22%), which was statistically similar with C_4 (42.12%), C_6 (42.50%), C_7 (41.15) and 12(39.52%). The lowest fruit was set by C_5 (24.17%), which was statistically similar with C_9 (26.04). The Remaining hybrids were given the same results for this trait. Baki & stomuel (1993) and Rama & Kalloo (1989) reported that fruit set in the heat tolerant hybrids of tomato ranged from 1.9 to 46.97%, this finding agreed with the present investigation.

Table 4.1.2. Floral characteristics of 13 tomato hybrid lines

Hybrids	Days to 50% Flowering	No. of flowers / cluster	Viable pollen grains (%)
C_1	43 **de**	5.30 **ef**	54.13 **cd**
C_2	44 **cd**	5.07 **f**	54.60 **cd**
C_3	47 **b**	6.15 **c**	57.27 **b-d**
C_4	41 **f**	8.11 **a**	64.33 **a**
C_5	41 **f**	5.50 **de**	39.00 **f**
C_6	42 **ef**	7.29 **b**	54.10 **cd**
C_7	43 **de**	5.64 **de**	59.07 **a-c**
C_8	45 **bc**	5.80 **d**	51.65 **de**
C_9	48 **a**	5.63 **de**	54.93 **cd**
C_{10}	41 **f**	7.82 **a**	62.63 **ab**
C_{11}	43 **de**	5.58 **de**	48.40 **e**
C_{12}	43 **de**	7.80 **a**	57.43 **b-d**
C_{13}	44 **c-e**	7.87 **a**	56.36 **cd**
CV%	**3.07**	**4.33**	**8.23**

In a column, means followed by common letters under the same factor are not significantly different at 1% level by DMRT. 'C 'stands for cross or combination or hybrid line

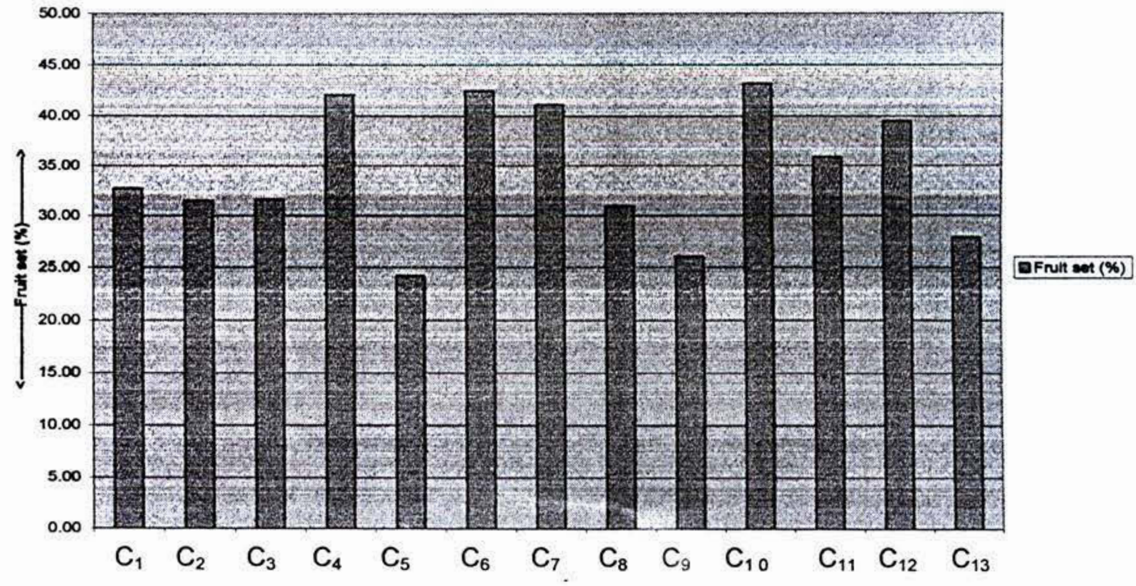

Figure 1. Fruit set (%) of 13 tomato hybrid lines
'C 'stands for cross or combination or hybrid line

Fruit length

Fruit length of thirteen (13) tomato hybrids differed significantly (Table 4.1.3). The longest (5.47 cm) fruit was found from the hybrid C_3 that was statistically similar to the hybrid C_4 (5.38 cm) and C_9 (5.15). The shortest (3.59 cm) fruit was found from the hybrids C_{10}. And the remaining hybrids were given more or less same results in this experiment (plate 4). Ahmad (2002) found similar result in an experiment of 49 tomato hybrids in summer season, which ranged from 1.94 cm to 5.46cm.

Fruit diameter

In case of fruit diameter the trend was also almost the same as in fruit length (Table 4.1.3). The ranges of fruit diameter were 5.96 cm to 3.50 cm (plate 4). The highest (5.96cm) diameter was obtained from C_5 followed by others. The lowest (3.50cm) diameter was obtained from C_{10} which was statistically similar with C_3 and C_6. The remaining hybrids were given the same result in this experiment. These findings were supported by Ahmad (2002).

Brix percent

No significant variation was found in case of brix percentage among the thirteen hybrids except C_6. Only the C_6 hybrids were given the lowest result (3.83%). With visual estimation full-ripened fruits were considered for this measurement. However, the results showed the range from 5.45% in C_4 to 4.28% in C_2 (Table 4.1.3). The result of brix percentage (%) was fully similar with the findings of Ahmad (2002).

Table 4.1.3. Fruit characteristics of 13 tomato hybrid lines

Hybrids	Fruit length (cm)	Fruit diameter (cm)	Brix percent
C_1	4.73 **c**	4.63 **d**	4.40 **e**
C_2	4.91 **bc**	5.21 **b**	4.28 **e**
C_3	5.47 **a**	3.82 **f**	4.65 **de**
C_4	5.38 **a**	4.84 **c**	5.45 **a**
C_5	4.96 **bc**	5.96 **a**	4.92 **cd**
C_6	4.12 **e**	3.63 **fg**	3.83 **f**
C_7	4.57 **cd**	4.53 **de**	5.02 **b-d**
C_8	4.57 **cd**	5.08 **b**	5.13 **a-c**
C_9	5.15 **ab**	4.95 **bc**	5.12 **a-c**
C_{10}	3.59 **f**	3.50 **g**	5.40 **ab**
C_{11}	4.09 **e**	4.27 **e**	4.98 **b-d**
C_{12}	4.70 **c**	4.66 **cd**	4.83 **cd**
C_{13}	5.13 **ab**	4.67 **cd**	5.17 **a-c**
CV%	**6.81**	**5.57**	**6.65**

In a column, means followed by common letters under the same factor are not significantly different at 1% level by DMRT. 'C 'stands for cross or combination or hybrid line

Number of fruits per cluster

Significant variation was found among the thirteen hybrids for fruits per cluster (Table 4.1.4). The number of fruits per cluster ranged from 1.35 to 3.43. The maximum 3.43 fruits were found from C_4, which is statistically similar to C_{10} (3.35). The minimum fruits were found from C_5 (1.35), which is statistically similar to C_2 and C_9. From the remaining hybrids C_6 and C_{12} were given statistically similar results, but C_7, C_3, C_{11} and C_{13} were closely related than the others.

Number of fruits per plant

Significant difference was observed for fruits number per plant among the hybrids. The number of fruits varied from 5.28 to 19.25. The highest (19.25) no. of fruits were obtained from the hybrid C_{12} . From the remaining hybrids C_4, C_6 and C_{10} showed the similar result than the others. The lowest numbers of fruits per plant were obtained from C_9 (5.28), which are statistically similar with C_2, C_3, C_8, C_{11} and C_{13}. The differences for fruits per plant among the hybrids are clearly demonstrated in Table 4.1.4. Phookan *et al.* (1990) conducted an experiment to evaluate 29 hybrids of tomato in relation to 8 different growth and yield attributing parameters under plastic house condition during summer season and found fruit number ranging from 2.67 to 70.00 which are good in agreement with the result of the present study. The result also has the similarity of the findings of Ahmad (2002).

Average fruit weight

Significant variation was found for average fruit weight among the hybrids as revealed from table 4.1.4. The highest (65.17g) average individual fruit weight was obtained from the hybrid C_2 followed by other and the lowest (19.00g) average individual fruit weight was obtained from the hybrid C_6 which is statistically similar with C_{10} and C_{12}. The remaining hybrids were closely related to each other. At night temperature of 14^0C, Went (1957) obtained tomato fruit three times than the size as obtained at 26^0C. The temperature range of the present study was 29.35^0C to 34.03^0C (Appendix 1). Ahmad (2002) also found the range of individual fruit weight from 5.25g to 43.38g among 25 heat tolerant hybrids which supports the findings of the present study.

Fruit yield per plant

There was no significant variation in respect of fruit yield per plant among the thirteen (13) hybrids. The highest (587.50g) fruit yield was obtained from the hybrid C_{12} and the lowest (221.50 g) fruit yield was obtained from the hybrid C_3. But the remaining hybrids were given the statistically similar result which is clearly demonstrated in Figure 2 and Appendix 3. Baki (1991) in an experiment on heat tolerant tomato under high temperature conditions (39°C day /28^0 C night) reported a yield of 410, 173 and 11g depending on the level of heat tolerance of the hybrids. Findings of Ahmad (2002) also support the results of this trait.

Table 4.1.4. Yield contributing characteristics of 13 tomato hybrid lines

Hybrids lines	No. of fruits / cluster	No. of fruits / plant	Average fruit weight (g)
C_1	1.77 **e-g**	9.86 **c**	44.33 **cd**
C_2	1.62 **f-h**	5.48 **ef**	65.17 **a**
C_3	1.96 **de**	6.34 **d-f**	33.50 **e**
C_4	3.43 **a**	14.91 **b**	28.67 **f**
C_5	1.35 **h**	8.72 **c-e**	49.00 **b**
C_6	3.10 **b**	16.22 **b**	19.00 **g**
C_7	2.31 **c**	8.87 **cd**	34.33 **e**
C_8	1.83 **ef**	6.24 **d-f**	40.50 **d**
C_9	1.47 **gh**	5.28 **f**	47.33 **bc**
C_{10}	3.35 **ab**	16.13 **b**	21.00 **g**
C_{11}	1.98 **de**	7.97 **c-f**	39.83 **d**
C_{12}	3.08 **b**	19.25 **a**	21.67 **g**
C_{13}	2.20 **cd**	7.57 **c-f**	42.67 **d**
CV%	**11.10**	**24.51**	**9.93**

In a column, means followed by common letters under the same factor are not significantly different at 1% level by DMRT

'C' stands for cross or combination or hybrid line

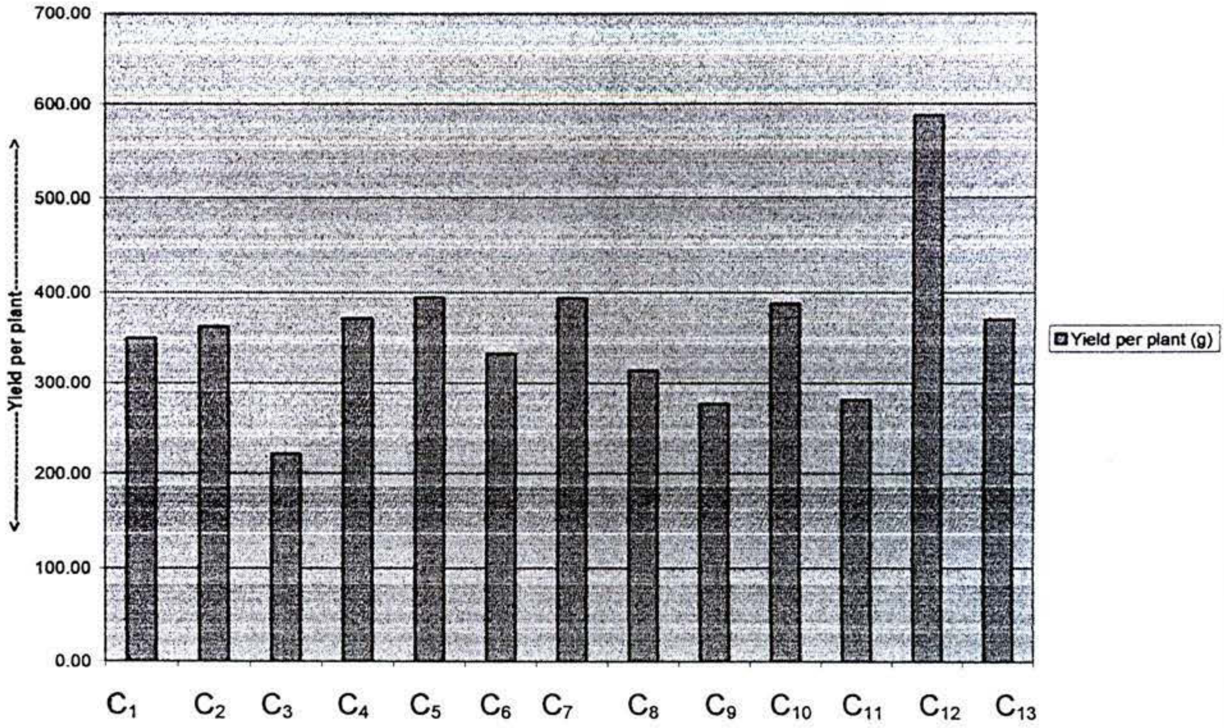

Figure 2. Fruit yield (g) per plant of 13 tomato hybrid lines

'C 'stands for cross or combination or hybrid line

4.2 Effect of hormone and no-hormone on tomato hybrid lines

Number of branches per plant was not significantly differed but plant height (cm) at last harvest was significantly affected by the treatment (Table 4.2.1). Number of branches per plant and plant height (cm) at last harvest were statistically identical. Higher plant height (cm) was obtained by the non-hormonal treatment.

Table 4.2.1. Effect of hormone and no-hormone on branch per plant & plant height in 13 tomato hybrid lines

Treatment	No of branches / Plant	Plant height (cm) at last harvest
H	4.37 **a**	96.68 **b**
NH	4.14 **a**	104.50 **a**

In a column, means followed by common letters under the same factor are not significantly different at 1% level by DMRT. H=Hormone and NH=No-hormone

All the parameters studied were insignificantly affected by the hormone except percent fruit set (Table 4.2.2). The highest (44.65) percent fruit set was observed by the hormonal treatment over non-hormonal treatment (24.46). Increasing fruit set by using the plant growth regulator "Tomatotone" were also reported by AVRDC (1990).

Table 4.2.2. Effect of hormone and no-hormone on floral characteristics in 13 tomato hybrid lines

Treatment	Days to 50% Flowering	No. of flowers / cluster	Viable pollen grains (%)	Fruit set (%)
H	43.82	6.43	54.92	44.65 **a**
NH	43.82	6.42	54.92	24.46 **b**

In a column, means followed by common letters under the same factor are not significantly different at 1% level by DMRT. H=Hormone and NH=No-hormone

Both fruit length (cm) and brix percent were insignificantly but fruit diameter was significantly affected by the hormone which is shown in table 4.2.3. Although fruit length was insignificantly affected but hormonal treatment gave better result over non-hormonal treatment. Hormonal treatment produced the largest (4.52 cm) fruit diameter compare to non-hormonal treatment (4.37 cm). When tomatoes are grown under unfavorable condition with application of synthetic plant growth regulators, it is claimed that the treatment increase fruit set and fruit size, AVRDC (1990).

Table 4.2.3. Effect of hormone and no-hormone on fruit characters in 13 tomato hybrid lines

Treatment	Fruit length (cm)	Fruit diameter (cm)	Brix percent
H	4.61	4.52 **a**	4.86
NH	4.51	4.37 **b**	4.86

In a column, means followed by common letters are not significantly different at 1% level by DMRT. H=Hormone and NH=No-hormone

The hormone significantly influenced all of the studied parameters (Table 4.2.4). Number of fruit per cluster, number of fruits per plant, average fruit weight in gram and yield per plant in gram were produced higher product by the hormonal treatment than that of non-hormonal treatment. By giving the hormonal treatment, the highest (444.72 g) yield per plant obtained over non-hormonal treatment (269.44 g). The same trend was also observed in respect of remaining parameters in this table. AVRDC (1990) reported that fruit yield increased by using hormone "Tomatotone".

Table 4.2.4. Effect of hormone and no-hormone on yield contributing characteristics in 13 tomato hybrid lines

Treatment	No. of fruits / cluster	No. of fruits / plant	Individual fruit weight (g)	Yield / Plant (g)
H	2.92 **a**	12.60 **a**	40.90 **a**	444.72 **a**
NH	1.61 **b**	7.83 **b**	34.03 **b**	269.44 **b**

In a column, means followed by common letters under the same factor are not significantly different at 1% level by DMRT. H=Hormone and NH=No-hormone

4.3 Interaction effect of hormone and no-hormone on tomato hybrid lines

The interaction effect of hormone and no-hormone on the number of branches per plant and plant height (cm) at last harvest in 13 tomato hybrids is presented in table 4.3.1. In case of branching habit and plant height, no significant variation was found by the combined treatments but number of branches per plant was slightly increased by the hormonal application over no-hormone. The highest (8.07) number of branches per plant was obtained from the treatment HC_5 over NHC_5 (7.13). Number of branches per plant 3.53 and 3.97 were given by the treatment HC_7, HC_{11} and HC_{12} respectively which is slightly lower than the treatment NHC_7 (2.57), NHC_{11} (4.00) and NHC_{12} (4.83). The remaining hormonal treatments except HC_3 and HC_9 were given a little bit higher result over non-hormonal treatments.

The highest (116.83) plant height was given by the treatment NHC_6 over HC_6 (112.20 cm). Irrespective of hybrids the remaining non-hormonal treatments were given a little bit higher result over hormonal treatment.

Table 4.3.1. Interaction effect on branch per plant & plant height in 13 tomato hybrid lines

Hybrid lines	No. of Branches / Plant		Plant height (cm) at last harvest	
	H	NH	H	NH
C_1	7.30	6.70	98.03	104.83
C_2	5.87	4.70	105.93	111.63
C_3	3.13	3.13	87.90	92.53
C_4	3.33	3.07	105.50	109.90
C_5	8.07	7.13	91.57	104.17
C_6	4.70	4.13	112.20	116.83
C_7	2.47	2.57	83.10	103.07
C_8	3.77	3.27	111.77	115.60
C_9	3.50	3.50	91.37	96.50
C_{10}	4.23	3.77	102.00	110.93
C_{11}	3.53	4.00	89.57	99.57
C_{12}	3.97	4.83	92.73	104.83
C_{13}	3.00	2.90	85.13	88.03

'C 'stands for cross or combination or hybrid lines.
H=Hormone and NH=No-hormone

An interaction effect was noticed among the floral characteristics in 13 tomato hybrids (Table 4.3.2). Days to 50% flowering, number of flowers per cluster and percent of viable pollen grain were insignificantly but percent fruit set was significantly influenced by the combined treatment. In this experiment hormonal and non-hormonal treatment on days to 50% flowering and percent viable pollen grain were given the same result.

The highest number (8.15) of flowers per cluster was obtained from the treatment HC_4 that was slightly higher than NHC_4 (8.08). It was observed that the treatment HC_5 (5.46), HC_6 (7.20), HC_7 (5.56), HC_{10} (7.58), HC_{11} (5.48) and HC_{12} (7.73) were given a little bit lower result compare to the treatment NHC_5 (5.54) NHC_6 (7.37), NHC_7 (5.72), NHC_{10} (8.05), NHC_{11} (5.68) and NHC_{12} (7.88). The remaining treatment HC_1, HC_2, HC_3, HC_8, HC_9 and HC_{13} were given the gradually decreased result with the treatment NHC_1, NHC_2, NHC_3, NHC_8, NHC_9 and NHC_{13}.

The highest percent fruit set (56.01) was given by the treatment HC_4 followed by the treatment HC_{10} (55.22) and they were statistically similar and gave the best result over the non-hormonal treatment NHC_4 (28.24) and NHC_{10} (31.23). Significant result was also given by the remaining treatment and they were statistically different from each other. However, hormonal treatment gave significantly increased result with the non-hormonal treatment. AVRDC (1990) reported that the fruit setting is improved particularly in varieties by the application of plant growth regulators.

Table 4.3.2. Interaction effect on floral characteristics in13 tomato hybrid lines

Hybrid lines	Days to 50% Flowering		No. of flowers / cluster		Viable pollen grains (%)		Fruit set (%)	
	H	NH	H	NH	H	NH	H	NH
C_1	43.67	43.67	5.44	5.16	54.13	54.13	42.30 **c-e**	23.18 **j-l**
C_2	44.67	44.67	5.28	4.86	54.60	54.60	41.81 **c-e**	21.09 **k-m**
C_3	47.00	47.00	6.23	6.06	57.27	57.27	39.58 **d-f**	23.55 **j-l**
C_4	41.00	41.00	8.15	8.08	64.33	64.33	56.01 **a**	28.24 **h-j**
C_5	41.33	41.33	5.46	5.54	39.00	39.00	34.18 **f-h**	14.15 **m**
C_6	42.67	42.67	7.20	7.37	54.10	54.10	50.75 **ab**	34.25 **f-h**
C_7	43.33	43.33	5.56	5.72	59.07	59.07	46.26 **b-d**	36.04 **e-g**
C_8	45.67	45.67	5.89	5.70	51.65	51.65	44.84 **b-d**	17.02 **lm**
C_9	48.67	48.67	5.63	5.63	54.93	54.93	33.21 **f-h**	18.87 **k-m**
C_{10}	41.00	41.00	7.58	8.05	62.63	62.63	55.22 **a**	31.23 **g-i**
C_{11}	43.00	43.00	5.48	5.68	48.40	48.40	47.08 **bc**	24.67 **i-k**
C_{12}	43.33	43.33	7.73	7.88	57.43	57.43	49.68 **ab**	29.35 **g-j**
C_{13}	44.33	44.33	7.99	7.76	56.36	56.36	39.45 **d-f**	16.39 **lm**

In a column, means followed by common letters under the same factor are not significantly different at 1% level by DMRT. 'C 'stands for cross or combination or hybrid lines
H=Hormone and NH=No-hormone

The interaction effect of hormone and no-hormone on fruit characteristics in 13 tomato hybrids has been furnished in the table 4.3.3. Fruit length (cm), Fruit diameter (cm) and Brix percent were insignificantly influenced by the combined treatment. The highest fruit length (5.47 cm) was given by the treatment HC_3 followed by the treatment NHC_3 (5.47 cm). Though it was insignificant, the treatment NHC_2 (4.93 cm), NHC_7 (4.60 cm) and NHC_{13} (5.19 cm) were given a little bit higher result than that of HC_2 (4.89 cm), HC_7 (4.55 cm) and HC_{13} (5.07 cm). The remaining hormonal treatment gave better result than no-hormone treatment.

In case of fruit diameter, the treatment HC_5 was given the highest (6.03 cm) result compare to NHC_5 (5.89 cm). The treatment HC_6 (3.58 cm) gave slightly lower result than that of NHC_6 (3.69 cm). The remaining hormonal treatment gave better result than no-hormone treatment irrespectively. However, the hormonal treatment gave larger fruit size than no-hormone. The findings of AVRDC (1990) demand that fruit size slightly increased by using hormone.

The highest (5.50) brix percent was found from the treatment HC_4 and HC_{10} over the treatment NHC_4 (5.40) and NHC_{10} (5.30), which was closed to the treatment HC_7 (5.13), HC_9 (5.27), HC_{11} (5.10), HC_{13} (5.20), NHC_5 (5.20), NHC_8 (5.30) and NHC_{13} (5.13). But the treatment HC_1 (4.27), HC_2 (4.20), HC_5 (4.63), HC_6 (3.77) and HC_8 (4.97) gave a little bit lower result than that of NHC_1 (4.53), NHC_2 (4.37), NHC_5 (5.20), NHC_6 (3.90) and NHC_8 (5.30) respectively.

Table 4.3.3. Interaction effect on fruit characters in 13 tomato hybrid lines

Hybrid lines	Fruit length (cm)		Fruit diameter (cm)		Brix percent	
	H	NH	H	NH	H	NH
C_1	4.90	4.57	4.73	4.53	4.27	4.53
C_2	4.89	4.93	5.47	4.95	4.20	4.37
C_3	5.47	5.47	3.85	3.79	4.73	4.57
C_4	5.39	5.17	4.83	4.76	5.50	5.40
C_5	5.03	4.89	6.03	5.89	4.63	5.20
C_6	4.21	4.03	3.58	3.69	3.77	3.90
C_7	4.55	4.60	4.59	4.47	5.13	4.90
C_8	4.60	4.53	5.33	4.82	4.97	5.30
C_9	5.25	5.04	5.09	4.81	5.27	4.97
C_{10}	3.62	3.57	3.57	3.43	5.50	5.30
C_{11}	4.15	4.04	4.30	4.23	5.10	4.87
C_{12}	4.78	4.63	4.76	4.57	4.87	4.80
C_{13}	5.07	5.19	4.71	4.62	5.20	5.13

'C' stands for cross or combination or hybrid line
H=Hormone and NH=No-hormone

The interaction effect of hormone and no-hormone on yield contributing characteristics in 13 tomato hybrids is given in the table 4.3.4. The Number of fruits per cluster, the number of fruits per plant and yield per plant were significantly influenced by the combined treatment. It was observed that number of fruits per cluster, number of fruits per plant, individual fruit weight in gram and yield per plant in gram increased gradually with the hormonal treatment (figure 3 & 4). The highest number of fruits per cluster (4.57) was obtained from the treatment HC_4 that was closed to the treatment HC_{10} (4.18), followed by the rest, which were statistically different from each other. The treatment HC_{12} was given the highest number (26.00) of fruits per plant over the treatment NHC_{12} (12.50) followed by the rest which were statistically different from each other except treatment HC_4, HC_6 and HC_{10}, because the treatment HC_4 (19.26), HC_6 (18.87) and HC_{10} (18.96) gave the statistically similar result. These findings are in agreement with AVRDC (1997) that fruits per plant are increased under polytunnel with "Tomatotone" application. The findings of AVRDC (1997) demand that fruits per plant, individual fruit weight and yield per plant increased under poly tunnel condition with hormonal treatment.

Table 4.3.4. Interaction effect on yield contributing characteristics in 13 tomato hybrid lines

Hybrid lines	No. of fruits / cluster				Individual fruit weight (g)	
	H		NH		H	NH
C_1	2.30	e-g	1.24	hi	47.33	41.33
C_2	2.21	e-g	1.04	hi	71.00	59.33
C_3	2.47	ef	1.44	h	37.67	29.33
C_4	4.57	a	2.29	e-g	32.00	25.33
`C_5	1.87	g	0.82	i	53.67	44.33
C_6	3.67	c	2.52	ef	20.33	17.67
C_7	2.56	e	2.05	fg	36.00	32.67
C_8	2.68	e	0.97	hi	44.67	36.33
C_9	1.87	g	1.06	hi	50.33	44.33
C_{10}	4.18	ab	2.52	ef	23.67	18.33
C_{11}	2.56	e	1.40	h	43.00	36.67
C_{12}	3.84	bc	2.32	e-g	25.33	18.00
C_{13}	3.12	d	1.27	hi	46.67	38.67

In a column, means followed by common letters under the same factor are not significantly different at 1% level by DMRT. 'C' stands for cross or combination or hybrid line, H=Hormone and NH=No-hormone

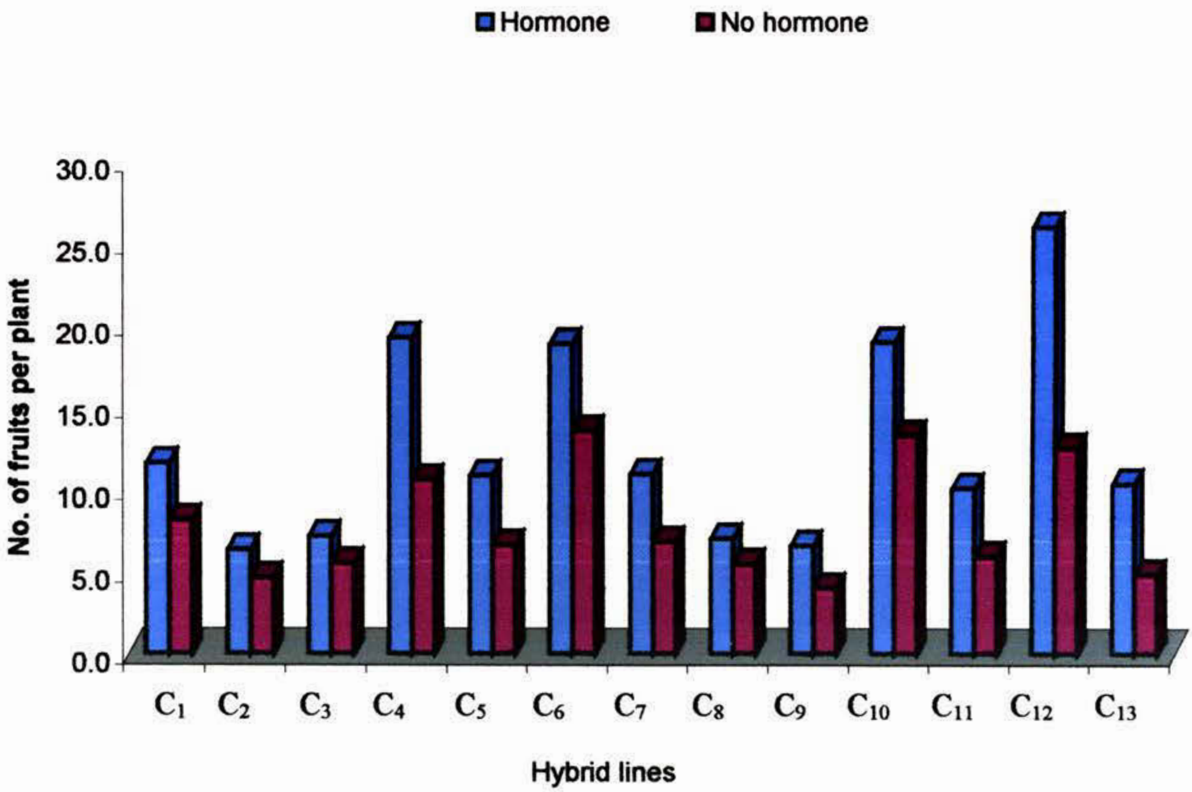

Figure 3. Effect of hormone on Fruits per plant of 13 tomato hybrid lines

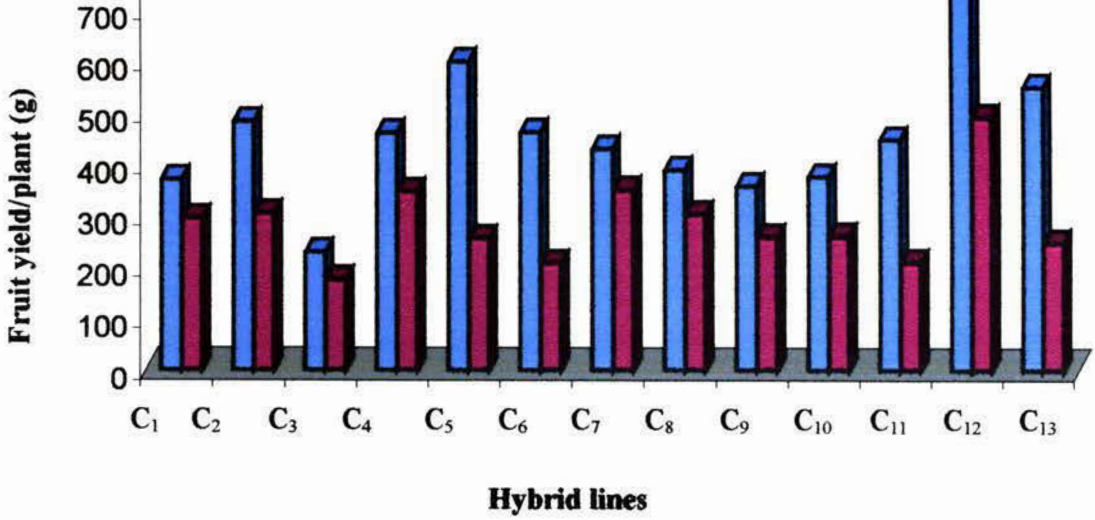

Figure 4. Effect of hormon on yield per plant of 13 tomato hybrid lines

Plate 4. Fruits of different hybrid lines

CHAPTER 5

SUMMERY

The present study dealt with the performance of thirteen (13) heat tolerant tomato hybrid lines. A field experiment was conducted at the Horticulture farm of BARI, Joydebpur, Gazipur during May 2004 to August 2004. The objectives of the experiment were to evaluate the effect of hormone on the yield performance of 13 heat tolerant tomato hybrid lines in summer. The experiment was laid out in RCBD (Factorial) with 3 (three) replications. The results of the study showed a marked variation in different yield component traits and yield. For days to 50% flowering among the hybrid lines C_4, C_5, and C_{10} took minimum duration (41 days) for flowering. Number of flowers per cluster also showed wide variation ranging from 5.07 to 7.87, but number of fruits per cluster was low. Three lines had 24-30% fruit set and the rest 10 had more than 30% fruit set. In case of average fruit weight, the highest fruit weight was obtained in C_2 (65.17 g) and the lowest was 19.00 g in C_6. Yield per plant ranged from 588 g in C_{12} to 222 g in C_3. Fruit length and fruit diameter also varied but not so high. It also revealed that all the studied parameters in the experiment were significantly influenced by the hormonal treatment. The highest yield of fruits per plant (445 g) was recorded from the hormone-applied line, which was 65 % higher than no-hormone applied line. Heat tolerant tomato hybrid line C_{12} with the hormone application resulted better yield contributing characters and produced the highest yield of fruit per plant (588 g).

CHAPTER 6

CONCLUSION & RECOMMENDATION

Conclusion

The following conclusions have been made on the basis of findings of the present investigation:

- Thirteen hybrids of tomato have shown wide range of variability's among them for yield and yield component characters. The accession C_4, C_6, C_7, C_{10} and C_{12} performed better as they had fairly high percentage of fruit set under the hot-humid summer conditions of Bangladesh.
- Hormonal application helps in increasing fruit set and yield significantly over natural setting under hot-humid condition.
- The findings as a whole showed that hybrid variety development programme for summer season in tomato may help to fulfill the demand of summer tomato variety in Bangladesh.

Recommendations

- Among the thirteen (13) hybrids, the hybrids such as C_4, C_6, C_{10} and C_{12} were superior to other hybrids in respect of yield, fruit set and fruits per plant which may be selected as a variety.
- For developing more heat tolerant hybrids further study towards collection, identification and utilization in breeding programme may be und ertaken.

CHAPTER 7

LITERATURE CITED

Abdullah, A. A. and. Verkerk, K 1968. Growth, flowering and fruit-set of the tomato at higher temperature. Neth. J. Agric. Sci. 16 : 71 – 76.

Ahmad, S. 2002. Genetics of fruit set and related traits in tomato under hot – humid conditions. Ph. D. Thesis. BSMRAU. pp. 44 – 180.

Ahmed, S. U.; Shaha, H. K. and Sharfuddin, A. F. M. 1988. Study of heterosis and correlation in tomato. Thai Journal of Agricultural Science. 21 (2) : 117-123.

Alvarez, M. 1985. Evaluation of tomato hybrids in summer. II. Heterosis for morphological characteristics and fruit weight. Cultivars-Tropicals. 7 (1) : 37-45.

Anonymous 1998. Developed vegetables varieties and technologies. Olericulture division, HRC, BARI, Joydebpur, Gazipur. pp. 25 – 38.

Anonymous. 1988. Production Year Book. Food and Agricultural Organization of the United Nations, Rome, Italy. 42 :190-193.

Anonymous. 1995. Agro-climatological data. Agromet Division, Bangladesh Meteorological Department, Joydebpur, Gazipur. pp. 35 – 65.

Aung, L. H. 1976. Effect of photoperiod and temperature on vegetative and reproductive responses of *Lycopersicon esculentum* Mill. J. Amer. Soc. Hort. Sci. 101 : 358-360.

AVRDC. 1990. Progress Report. 1986. Asian Vegetable Research and Development Center, Shanhua ,Tainan ,Taiwan. p. 541.

AVRDC. 1997. Progress-report. Asian Vegetable Research and Development Center, Shanhua, Taiwan. p. 352.

Baki, A. A. 1991. Tolerance of tomato cultivars and selected germplasm to heat stress. Journal of the American Society for Horticultural Science. USDA-ARS Vegetable. pp. 48 – 55.

Baki, A. A. and Stommel, J. R. 1995. Pollen viability and fruit set of tomato genotypes under optimum and high temperature regimes. HortScience. 30 (1): 115-117.

Baki, A. A. and Stomuel, J. R. 1993. Pollen viability and fruit set of heat tolerant and sensitive tomato genotypes under optimum and high temperature regimes. HortScience. 28 (5): 135 – 145.

Bar-tazur, A.; Rudich, J. and Bravdo, B. 1985. High temperature effect on CO_2 gas exchange in heat tolerant and sensitive tomatoes. J. Amer. Soc. Hort. Sci. 110 : 582-586.

Berry, S. Z. and Uddin, M. R. 1988. Effect of high temperature on fruit set in tomato cultivars and selected germplasm. HortScience. 23 : 606-608.

Bodo, R. T. 1991. Comparison of different pollen viability assays to evaluate pollen fertility of potato diploids. Euphytica. 56 : 143-148.

Brammer, H. 1971. Soil resources, soil survey project, Bangladesh. AGL: SF/Pck. 6. technical report. 3. p. 8.

Carroll, C. P. and Low, P. I. 1976. Aspects of male fertility in group Tubersum diplods. Potato Res. 19 (1) : 109-121.

Charles, W. B. and Harris, R. E. 1972. Tomato fruit set at high and low temperatures. Can. J. Plant Sci. 52 : 497-506

Chaudhury, R. C. and Khanna, K. R. 1972. Exploitation of heterosis in tomato yield and components. South Indian Hort. 20 : 59-65.

Cheema, D. S.; Surjan, S. and Kuo, C. G. 1993. Variability in heat-tolerant tomato germplasm. Adaptation of food crops to temperature and water stress: proceedings of an international symposium, Taiwan, 13-18 August 1992. Department of Vegetable Crops, Landscaping and Floriculture, Punjab Agricultural University, Ludhiana 141004, India. 12 : 316-320.

Chen, H. H., Shen, Z.Y. and Li, P. H. 1982. Adaptability of crop plants to high temperature stress. Crop Sci. 22 : 719-725.

Dane, F.; Hunter, A. G. and Chambliss, O. L. 1991. Fruit set, pollen fertility and combining ability of selected tomato genotypes under high temperature field conditions. J. Amer. Soc. Hort. Sci.116 (5) : 906-910

Dinar, J., Rudich, J. and Zamski, E. 1983. Effects of heat stress on carbon transport from tomato levels. Annals of Botany. 51 : 97-103.

Dinar, M. J., Rudich, J. and Zamski, E. 1982. Effect of heat stress on carbon transport from tomato leaves. Annals of Botany. 50 : 97 – 103.

El-Ahmadi, A. B. and Stevens, M. A. 1979b. Genetics of high temperature fruit set in the tomato. J. Amer. Soc. Hort. Sci. 104 : 691-696.

El-Ahmadi, A. B. and Stevens, M. A. 1979a. Reproductive responses of heat tolerant tomatoes to high temperatures. J. Amer. Soc. Hort. Sci. 104 : 686-691.

El-Mahdy, I.; E-Metwally, G.; El-Fadly and Mazrouh, A. Y. 1990. Inheritance of yield and fruit setting quality of some tomato crosses grown under heat stress conditions in Egypt. J. Agric. Res. Tanta Univ., 16 (3) : 517-526.

E-Metwally; El-Zewily, A.; Hassan, N. and Zanata, O. 1996. Inheritance of fruit set and yield of tomato under high temperature conditions in Egypt. 1st Egypt-Hung. Hort. Conf., 1 : 112-122.

Florido, M.; Lara, R. M.; Plana, D. and Alvarez, M. 1999. Establishment of an efficient method for evaluating heat tolerance in tomato (Lycopersicon spp.). Cultivos-Tropicales. 20 (2) : 69-73.

Gardner, C.O. 1968. Principles of Genetics. John Willey and Sons. New York. pp. 221 – 242.

Gomez, K. A. and Gomez, A. A. 1984. Staistical procedures for Agricultural Research. John Wlley and Sons. Inc. New York. pp. 67 – 215.

Goreta, S.; Gudelj, Velaga, Z. and Bucan, L. 2000. Yield components of determinate tomato (Lycopersicon esculentum Mill.) cultivars. Agriculturae-Conspectus-Scientificus-Poljoprivredna-Znanstvena-Smotra. Institute for Adriatic Crops and Karst Reclamation, Put Duilova 11, 21000 Split, Croatia. 65 (3) : 169-174.

Gowen, J. W. 1952. Development of the heterosis concept. pp. 152 – 178. In: Heterosis (Hayes, H.K. ed.) Iowa State College Press. Amer. Iowa.

Hanna, H. Y.; Adams, A. J. and Black, L. L. 1991. LHT24: A new heat-tolerant tomato. Louisiana-Agriculture. Citrus Research Station, Rt. 1, Box 628, Port Sulphur, LA 700083, USA. 35 (1) : 20.

Hanna, H. Y.; McBride, J. M. and Romaine, D. J. 1994. Feasibility of extending tomato harvest season by planting heat tolerant cultivars. Proceedings-of-the-Florida-State-Horticultural-Society. USA. 107 : 111-113.

Hanna, H. Y. and Hernandez, T. P. 1979. Heat tolerance in tomato. Hort. Sci. 14 (2) : 121.

Hanna, H.Y.; Hernamdez, T.P. and Adams, A.J. 1983. Effect of heat stress on tomato flower structure and fruit set. Lousiana Agriculture. 27 (2) : 8-9.

Hanna, Y. and Hernandej, T. P. 1980. A study of several characters related to heat tolerance in tomato. HortScience . 15 (3): 45 – 56.

Hassan, J. K. 1991. Tomato hybrid seed production in unheated plastic tunnels. Zoldsegtermesztesi-Kutato-Intezet-Bulletinje. Zoldsegtermesztesi Kutato Intezet, Kecskemet, Hungary. 24 : 93-96.

Heiser, C. J. 1969. Love Apples. In: Nightshades: The paradoxical plants. Freeman. San Francisco, CA. pp. 53-105.

Ho, L. C. 1979. Regulation of assimilate translocation between leaves and fruits in the tomato. Annals of Botany, 43 : 437 – 448.

Howlett, F. S. 1936. The effect of carbohydrate and nitrogen deficiency upon microsporogenesis and the development of the male gametophyte in the tomato, *Lycopersicon esculentum,* Mill. Annals of Botany. 50 : 767-803.

Ibrahim, M. M. 1984. Genetic and physiological studies on heat and cold tolerance in tomatoes. Ph.D. Thesis. Cairo University. pp. 35 – 68.

Iwahori, S. 1965. High temperature injuries in tomato. IV. Development of normal flower buds and morphological abnormalities of flower buds treated with high temperature. J. Japan. Soc. Hort. Sci. 34 : 33-41.

Iwahori, S. 1967. Auxin of tomato fruit at different stages of its development with a special reference to high temperature injuries. Plant Cell Physiol. 8 : 15-22.

Iwahori, S. and Takahashi, K. 1964. High temperature injuries in tomato. III. Effects of high temperature on flower buds and flowers of different stages of development. J. Japan. Soc. Hort. Sci. 33 : 33-41.

Iwahori, S.; Sakiyama, R. and Takahashi, K. 1963. High temperature injuries in tomatoes. I. Effects of different temperatures on fruit setting and yield of seedlings treated at different stages of growth. J. Japan. Soc. Hort. Sci. 32 : 197-204.

Jamwal, R. S.; Pattan, R. S. and Saini, S. S. 1984. Hybrid vigour and combining ability in tomato. South Indian Hort. 32 (2) : 69-74.

Jenkins, J. A.1948.The origins of the cultivated tomato. Econ. Bot. 2 :379.

Johanson, S. P. and Hall, W. C. 1953. Vegetative and fruiting response of tomatoes to high temperature and light intensity. Bot. Gaz. 114 : 449-460.

Kakizaki, Y. 1930. Breeding crossed eggplants in Japan. J. Hered. 21 : 253-258.

Kuo, C. G., Chen, B. W. and Chen, M. H. 1978. Tomato fruit-set at high temperature. 1st International Symposium on Tropical Tomato. AVRDC, Taiwan. pp. 94 – 108.

Legon, Martin C.; Diaz, N. and Garcia, P. G. 1984. Performance of tomato hybrids and their parents in summer. Centro Agricola. 11 (1) : 35-44.

Levy, A.; Robinowitch, H.O. and Kedar, N. 1978. Morphological and physiological characters affecting flower drop and fruit set of tomatoes at high temperature. Euphytica. 27 : 211-218.

Lin, T. C. and Hong, W. T. 1989. Development of the new summer tomato variety Taichung Asveg 4. Bulletin-of-Taichung-District-Agricultural-Improvement-Station. Taichung District Agricultural Improvement Station, Tatsuen, Changhua, Taiwan. 25 : 55-64.

Lohas, D. P. and Peat, W. E. 1998. Floral characteristics of heat tolerant and heat sensitive tomato (*Lycoperisicon esculuntum* Mill.) cultivars at high temperature. Scientia Horticulture. 73 : 53-60.

Mercade, J. A.; Trigi, M. M.; Reid, M.S.; Valpuesta, V. and Quesada, M. A. 1997. Effects of low temperature on pollen morphology and fertility: Evidence of cold induced exine alternations. J. Horti. Sci. 72 : 317-326.

Opena, R. T.; Shanmugasundaram, S.; Yoon, J. Y. and Fernandez, G. C. F. 1987b. Crop improvement program to promote vegetable production in the tropics. Pages 1-17 in: Breeding of horticultural Crops. W. N. Chang, R. T. Opena and J. B. Peterson eds. Food and Fertilizer Technology Center, Taipei, Taiwan.

Opena, R. T. 1985. Development of tomato and Chinese cabbage cultivars adapted to the hot humid tropics. Acta. Hort.153 : 421-436.

Opena, R. T. and Lo, S. H., 1979a. Genetics of heat tolerance in heading Chinese cabbage. Hort. Sci. 14 : 33-34.

Opena, R. T.; Chen, J. T.; Kuo C. G. and Chen, H. M. 1993. In: Adoptation of food crops to temperature and water stress. Kuo, C. George (ed.). Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan (Roc). p. 531.

Opena, R. T.; Kuo, C. G. and Yoon, J. Y. 1987a. Breeding for stress tolerance under tropical conditions in tomato and heading Chinese cabbage. In: Chang, W.N. Mac Gregor, P.W. and Bay-Peterson, J. (ed.). Improved vegetable production in Asia. Food and fertilizer Technol. Ctr., Taipei, Taiwan. pp. 88-109.

Opena, R. T.; Green, S. K.; Talekar, N. S. and Chen, J. T. 1989. Genetic improvement of tomato adaptability to the tropics: Progress and future prospects. AVRDC Publication No. 89-317, Shanhua, Taiwan. pp. 88 – 119.

Pereira, J. F. M. and Reisser, J. C. 1998. Sowing date of tomato in plastic house for out-of-season production: summer-autumn crop. Agropecuaria-Clima-Temperado. Embrapa Clima Temperado, Cx. Postal 403, CEP 96001-970, Pelotas (RS), Brazil. 1 (1): 73-77.

Phookan, D. B.; Talukdar, P.; Shadeque, A. and Chakravarty, B.K. 1990. Genetic variability and heritability in tomato (*Lycopersicon esculuntum*) genotypes during summer season under plastic-house condition. Indian J. Agric. Sci. 68 (6) : 304-6.

Picken, A. J. F. 1984. A review of pollination and fruit set in tomato (*Lycopersicon esculuntum* Mill.). HortScience. 59 : 1-13.

Rahman, S. M. L.; Nawata, E. and Sakuratani, T. 1998. Effects of temperature and water stress on growth, yield and physiological characteristics of heat-tolerant tomato. Japanese-Journal-of-Tropical-Agriculture. 42 (1) : 46-53.

Rana, M. K. and Kalloo, G. 1989. High temperature tolerance in tomato: Evaluation of genotypes. Veg. Sci. 16 (2): 156-167.

Rashid, M. M. 1993. Shabji Biggan. Bangla Academi, Dhaka. pp. 192 – 219.

Rick, C.M. and Dempsey, W.H. 1969. Position of the stigma in relation to fruit setting of the tomato. Bot. Gaz. 130: 180-186.

Rudich, J.; Zamski, E. and Regey, Y. 1977. Genotypic variation for sensitivity to high temperature in the tomato: pollination and fruit set. Bot. Gaz. 138 : 448-452.

Rylski, I. 1973. Effect of night temperature on shape and size of sweet pepper (*Capsicum annum* L.). J. Amer. Soc. Hort. Sci. 98 : 149-152.

Saito, T. and Ito, H. 1967. Studies on the growth and fruiting in the tomato. IX. Effects of the early environmental conditions and cultural Genotypess on the morphological and physiological development of flowers and the flower drop. J. Japan. Soc. Hort. Sci. 36 : 195-205.

Santipracha, Q. 1994. Yield trial of heat-tolerant table tomato in summer in Songkhla. Kaen-Kaset-Khon-Kaen-Agriculture-Journal. Department of Plant Science, Prince of Songkhla University, Hat Yai, Songkhla 90112, Thailand. 22 (2) : 60-65.

Scott, J. W.; Olson, S. M.; Howe, T. K.; Stoffella, P. J.; Bartz, J. A. and Bryan, H. H. 1995. Equinox' heat-tolerant hybrid tomato. HortScience. Gulf Coast Research and Education Center, University of Florida, 5007 60th Street East, Bradenton, FL 34203, USA. 30 (3) : 647-648.

Scott, J. W.; Volin, R. B.; Bryan, H. H. and Olson, S. M. 1986. Use of hybrids to develop heat tolerant tomato cultivars proceedings of the Florida State Horticultural Society. 99 : 311-314.

Shaheed, S. M. 1984. Soil of Bangladesh: General Soil Types. Soil Resources Development Institute (SRDI), Dhaka, Bangladesh. p. 3.

Shalaby, G. I.; Imam, M. K.; Nassar, A.; Wali, E. A. and. Mohamed. M. F. 1983. Studies on combining ability of some tomato cultivars under high temperature conditions. Assiut. J. Agric. Sci.14 : 35-56.

Shashi, K. and Satyanarayana, G. 1986. Breeding tomato for heat tolerance. Veg. Sci. 13 (2) : 247-249.

Shelby, R. A.; Greenleaf, W. H. and. Perterson, C. M. 1978. Comparative floral fertility in heat tolerant and heat sensitive tomatoes. J. Amer. Soc. Hort. Sci. 103 : 778-780.

Sidhu, A. S. and Singh, S. 1993. Studies on heterosis and divergence in tomato. Plant Breeding Abstracts. pp. 064-018.

Singh, R. K. and Singh, V. K. 1993. Heterosis breeding in tomato (*Lycopersicon esculentum* Mill.). Annals of Agril. Res. 14 (4) : 416-420.

Singh, R. K.; Singh, G. P. and Mandal, G.1983.Hetrosis in the inter-varietal crosses in tomato *(Lycopersicon esculentum* Mill.). In proceeding of National Seminar on the Production Technology of Tomatoes and Chillies. India. 53 : 67 – 92.

Sprague, G. F. 1983. Heterosis in maize. Theory and Practices. Page 17. In: Heterosis, Reappraisal of Theory and Practice. Monographs on Theoretical and Applied Genetics. Vol. 6. Frankel, R. (ed.). Springer–Verlag Berlin, Heidelberg.

Stevens, M. A. and Rudich, J. 1978. Genetic potential for overcoming physiological limitations on adaptability, yield and quality in the tomato. HortScience, 13 : 673 - 678.

Stevens, M. A., 1979. Breeding tomatoes for processing. In: Tropical tomato. R. Cowell (ed.). Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan. p. 290.

Sugiyama, T., Iwahori, S. and Takahasi, K. 1966. Effect of high temperature on fruit setting of tomato under cover. Acta Hort. 4 : 63-69.

Tindall J. E. and Williams, J. T. 1977. Tropical Vegetables and their Genetic Resources. Pp. 28 In: Grubben, G. H (ed.). IBPGR. Royal Tropical Institute. Amesterdam, Netherlands.

Villareal, R. L. and Lai, S. H. 1979.Development of heat tolerant tomato varieties in the tropics. In: 1st Intl. Symp. Tropical Tomato. W.R. Cowel l (ed.). Asian Vegetable Research and Development Center (AVRDC), Shanhua, Tainan, Taiwan. p. 290.

Villareal, R. L.; Lai, S. H. and Wong, S. H. 1978. Screening for heat tolerance in the genus *Lycopersicon*. HortScience. 13 : 479-481.

Went, F.W. 1957. The experimental control of plant growth. Chronica Botanica Co., Waltham, Mass. pp. 99-114.

Xu, D. F.; Wang, A. X. and Zhang, Y. X. 1994. Breeding a new tomato cultivar, Henan 5, for the summer and autumn seasons. China-Vegetables. Institute of Horticulture, Henan Academy of Agricultural Sciences, Zhengzhou, Henan 450002, China. 2 : 30-32.

Yordanov, M. (1983). Heterosis in tomato. Monogr. Theor. Appl. Genet. 6 : 189 – 219.

CHAPTER 8

APPENDICES

Appendix 1. Monthly mean temperature and relative humidity during the crop period at BARI, Joydebpur, Gazipur.

Year	Month	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
		Minimum	Maximum	Minimum	Maximum	
2004	May	24.35	33.71	77.92	91.65	225.8
	June	25.62	34.03	77.58	90.54	305.38
	July	27.15	32.58	80.52	90.48	204.56
	August	26.80	32.90	82.44	91.62	128.26

Source: Meterological Department, BARI, Gazipur.

Appendix 2. Analysis of variance for the selected heat tolerant tomato hybrid line

Source of Variation	df	Mean sum of square					
		Day's to 50% flowering	No. of flowers/ cluster	No. of fruits/ cluster	% of fruit set	No. of fruits / plant	%of viable pollen grain
Replication	2	2.667	0.118	0.840	138.002	14.011	224.622
Crosses (A)	12	31.291	7.962	3.203	262.384	134.294	243.574
Hormonal Status (B)	1	0.0001	0.002	33.137	7941.23	443.556	0.0001
Interaction (AB)	12	0.0001	0.089	0.341	38.647	16.335	0.0001
Error	50	1.813	0.078	0.063	15.236	6.272	20.438

Appendix 2 (Cont'd)

Source of Variation	df	Mean sum of square						
		Individual fruit weight(g)	Yield/ Plant(g)	Fruit length (cm)	Fruit diameter	No of branches /plant	Plant height (cm)	Brix percent (TSS)
Replication	2	36.12	35188.42	0.332	0.002	0.605	29.48	0.327
Crosses (A)	12	1025.72	45201.96	1.986	3.284	14.169	484.86	1.280
Hormonal Status (B)	1	920.82	599114.0	0.182	0.440	1.062	1191.8	0.001
Interaction (AB)	12	8.65	11994.38	0.025	0.064	0.454	35.945	0.104
Error	50	13.84	9044.73	0.097	0.061	0.283	41.09	0.104

Appendix 3. Effect of hybrid lines on %fruit set and yield /plant of 13 tomato hybrid lines

Hybrid lines	Fruit set (%)	Yield (g) / Plant
C_1	32.74 **cd**	349.83 **b**
C_2	31.45 **cd**	362.67 **b**
C_3	31.57 **cd**	221.50 **c**
C_4	42.12 **a**	371.17 **b**
C_5	24.17 **e**	394.17 **b**
C_6	42.50 **a**	332.50 **bc**
C_7	41.15 **a**	393.67 **b**
C_8	30.93 **cd**	313.67 **bc**
C_9	26.04 **e**	276.33 **bc**
C_{10}	43.22 **a**	387.50 **b**
C_{11}	35.88 **bc**	280.83 **bc**
C_{12}	39.52 **ab**	587.50 **a**
C_{13}	27.92 **de**	370.67 **b**
CV%	**11.30**	**26.63**

In a column, means followed by common letters under the same factor are not significantly different at 1% level by DMRT. 'C' stands for cross or combination or hybrid line, H=Hormone and NH=No-hormone

Appendix 4. Interaction effect of hormone and no-hormone on fruits and yield/plant of 13 tomato hybrid lines

Hybrid lines	Yield / Plant (g)		No. of fruits / plant	
	H	NH	H	NH
C_1	372 **j**	295 **n**	11.58 **c-e**	8.13 **d-i**
C_2	484 **e**	305 **n**	6.33 **f-i**	4.63 **i**
C_3	230 **q**	176 **s**	7.15 **e-i**	5.53 **hi**
C_4	463 **f**	349 **l**	19.26 **b**	10.56 **c-g**
C_5	601 **b**	257 **op**	10.83 **c-f**	6.60 **f-i**
C_6	464 **f**	208 **r**	18.87 **b**	13.57 **c**
C_7	432 **h**	352 **kl**	10.92 **c-f**	6.82 **e-i**
C_8	391 **i**	303 **mn**	7.01 **e-i**	5.46 **hi**
C_9	359 **k**	259 **o**	6.57 **f-i**	4.00 **i**
C_{10}	378 **j**	261 **o**	18.96 **b**	13.31 **c**
C_{11}	450 **g**	210 **r**	10.06 **c-h**	5.90 **g-i**
C_{12}	778 **a**	494 **d**	26.00 **a**	12.50 **cd**
C_{13}	553 **c**	249 **p**	10.31 **c-h**	4.82 **i**

In a column, means followed by common letters under the same factor are not significantly different at 1% level by DMRT. 'C' stands for cross or combination or hybrid line, H=Hormone and NH=No-hormone