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Performance of Different Tomato Genotypes in the Arid Tropics of Sudan during the Summer Season. II. Generative Development

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Abstract

Eleven tomato genotypes of diverse origin were grown in Shambat, University of Khartoum, Sudan, in a randomized block design with three replications for two successive seasons (2002/2003, 2003/2004). The same genotypes were firstly evaluated under glasshouse conditions at the Humboldt University of Berlin, Germany during 2002. Highly significant differences were encountered among the different genotypes for most of the generative characters, such as number of days to flowering, number of flowers per plant, number of fruits per plant, fruit fresh weight per plant and fruit set percentage. Based on results obtained from this study, the genotype 'Summerset' proved to be high yielding under high temperature conditions in comparison to other genotypes.

Keywords: tomato, genotypes, heat tolerance, high temperature, vegetative growth

1 Introduction

Heat stress is a major abiotic factor that limits tomato production during summer season in Sudan. High temperature negatively affects plant growth and survival and hence crop yield (Boyer, 1982). According to a recent study, each degree centigrade increase in average growing season temperature may reduce crop yield by up to 17% (Lobell and Asner, 2003).

Lack of tolerance to high temperature in most tomato genotypes presents a major limitation for growing an economic crop in regions where the temperature during part of the growing season, even for short durations, reaches 38 °C or higher (Abdul-Baki, 1991). Moreover, most of the presently cultivated varieties in Sudan are very much sensitive to hot climate and due to summer conditions with high temperature, their production and supply is limited almost to the winter period.

Hall (1992) reported that the genetics and physiology of heat tolerance in reproductive tissues have received comparatively little attention. A better understanding of the way that heat stress affects plants would help in the development of improved and better production systems to reduce the effects of high temperatures.

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Introduction of tomato genotypes of a promising nature has been important to the vegetable industry throughout the world. New varieties have enriched and advanced the agriculture of many countries.

The objectives of this study were to analyze the performance of different tomato genotypes in the arid tropics of Sudan during summer in order to investigate the effect of high temperature on the generative development. To have a full picture of the behavior of these genotypes, they were firstly evaluated under glasshouse conditions.

2 Materials and Methods

2.1 Field experiments

The experiments with eleven tomato genotypes of different origins were conducted for two successive seasons in the Department of Horticulture Orchard, Faculty of Agriculture, University of Khartoum, Shambat, Sudan (Latitude 15° 40‘N and longitude 32° 32‘ E). The cultivation data are described by ABDELMAGEED *et al.* (2009).

2.2 Glasshouse experiment

The same eleven genotypes used in the field experiment were firstly studied in the glasshouse at the Institute for Horticultural Sciences, Humboldt University of Berlin, Germany (Latitude 52° 30‘ N, Longitude 13° 25‘E) in the period mid-May-August, 2002. For more details, see ABDELMAGEED *et al.* (2009).

2.3 Data collected

Number of days to flowering, number of flowers per plant, number of fruits per plant, percent of fruits setting and fruit fresh weight (g plant^{-1}) were recorded according to ABDELMAGEED and GRUDA (2007, 2009b).

2.4 Data analysis

Analysis of variance was carried out according to the procedure described by GOMEZ and GOMEZ (1984) for the randomized complete block design to determine the significance of variation among the different genotypes. Mean separation was done by Duncan's multiple range test for P $\leq$ 0.05.

3 Results

The performance of different tomato genotypes under field during summer in Sudan and glasshouse conditions in Germany was investigated. The means under open field conditions are combined measurements of two seasons.

3.1 Glasshouse experiment

With regard to the number of days to flowering, there were significant differences among the different tomato genotypes (Table 1). The earliest genotypes were ‘CLN-1-0-3’,‘CLN-13R’, ‘CLN-16B’and ‘Summerset’, respectively and the latest genotypes were

'Drd 85 F_1', 'Kervic F_1' and 'Maverick F_1', respectively. The other genotypes were intermediate. There was a wide range of variation among the different genotypes for number of flowers under glasshouse conditions. 'CLN-1-0-3' produced the highest number of flowers per plant, while 'Omdurman' and 'UC 82-B' produced the lowest ones, respectively (Table 1).

Table 1: Number of days to flowering, number of flowers per plant, number of fruits per plant, fruit fresh weight per plant and fruit set percentage of diverse tomatoes grown under glasshouse conditions.

Genotype	*No. of days to flowering*	*No. of flowers plant^{-1}*	*No. of fruit plant^{-1}*	*Fruit fresh weight plant^{-1} (g)*	*Fruit set percentage*
CLN-1-0-3	47.00 $^{g\,*}$	104.72 ^{a}	50.70 ^{a}	542.98 ^{e}	48.46 ^{b}
CLN-16B	50.20 ^{def}	83.44 ^{b}	52.26 ^{a}	792.77 ^{cde}	64.18 ^{a}
CLN-26D	49.60 ^{ef}	69.30 ^{c}	30.94 ^{b}	599.48 ^{de}	44.41 ^{bc}
CLN-13R	49.20 ^{f}	56.42 ^{def}	20.02 ^{de}	565.40 ^{de}	35.35 ^{cd}
Strain B	52.40 ^{bc}	57.54 ^{def}	18.98 ^{de}	830.90 ^{bcde}	32.98 ^{d}
Maverick F_1	57.20 ^{a}	62.58 ^{def}	17.94 ^{e}	994.29 ^{abc}	28.71 ^{d}
UC 82-B	51.80 ^{bcd}	53.62 ^{fg}	27.04 ^{bc}	858.34 ^{bcd}	50.63 ^{b}
Drd 85 F_1	55.60 ^{a}	63.28 ^{cd}	21.06 ^{de}	1110.52 ^{ab}	33.33 ^{d}
Kervic F_1	56.40 ^{a}	60.48 ^{def}	18.20 ^{e}	976.05 ^{abc}	30.19 ^{d}
Omdurman	52.00 ^{bc}	48.58 ^{g}	17.16 ^{e}	1058.87 ^{abc}	35.34 ^{cd}
Summerset	51.20 ^{bcde}	61.18 ^{def}	28.34 ^{bc}	1193.04 ^{a}	46.30 ^{b}
Mean	52.15	64.65	27.23	865.69	41.25

* Means followed by the same letter(s) within each column are not significantly different at P $\leq$ 0.05, according to Duncan's multiple range test.

Regarding the number of fruits per plant, more fruits were produced from 'CLN-16B'and 'CLN-1-0-3'. 'CLN-26D', 'Summerset' and 'UC 82-B' gave a medium number of fruits per plant, while the other genotypes produced a low number of fruits (Table 1). There was a wide range of variation among the genotypes for fruit set percentage. 'CLN-16B' had the highest fruit set percentage, while 'UC 82-B', 'CLN-1-0-3', 'Summerset' and 'CLN-26D' were intermediate. The other genotypes had the lowest fruit set percentage (Table 1).

For fruit fresh weight, 'Summerset' exhibited the highest fruit fresh weight followed by 'Drd 85F_1', 'Omdurman', 'Kervic F_1' and 'Maverick F_1', while the other genotypes were either intermediate or low (Table 1).

3.2 Field experiment

A significant variation in number of days to flowering occurred among the different tomato genotypes (Table 2). The earliest genotypes were 'Omdurman', 'Summerset' and 'CLN-1-0-3', respectively and the latest genotypes were 'Maverick F_1', 'Drd 85 F_1' and 'Kervic F_1', respectively. The other genotypes were intermediate. There was a wide range of variation among the genotypes for the number of flowers grown under open field conditions during summer. 'Summerset' produced the highest number of flowers, while 'Drd85 F_1' the lowest one, the other genotypes were intermediate (Table 2).

Table 2: Number of days to flowering, number of flowers per plant, number of fruits per plant, fruit fresh weight per plant and fruit set percentage of diverse tomatoes grown under field conditions.

Genotype	*No. of days to flowering*	*No. of flowers plant^{-1}*	*No. of fruit plant^{-1}*	*Fruit fresh weight plant^{-1} (g)*	*Fruit set percentage*
CLN-1-0-3	50.33 ^{d*}	43.67 ^{bc}	9.67 ^{b}	58.96 ^{bc}	22.01 ^{ab}
CLN-16B	49.00 ^{de}	27.33 ^{bcd}	2.00 ^{cd}	6.45 ^{c}	6.01 ^{bc}
CLN-26D	51.67 ^{cd}	27.33 ^{bcd}	2.40 ^{cd}	27.21 ^{c}	8.59 ^{bc}
CLN-13R	51.00 ^{cd}	30.67 ^{abcd}	2.67 ^{cd}	18.90 ^{c}	8.33 ^{bc}
Strain B	57.33 ^{b}	26.00 ^{cd}	6.00 ^{bcd}	53.92 ^{bc}	26.76 ^{a}
Maverick F_1	59.00 ^{ab}	22.67 ^{cd}	0.67 ^{cd}	8.11 ^{c}	6.67 ^{bc}
UC 82-B	53.67 ^{c}	38.00 ^{abcd}	0.00 ^{d}	0.00 ^{c}	0.00 ^{c}
Drd 85 F_1	59.00 ^{ab}	21.00 ^{d}	3.33 ^{cd}	20.88 ^{c}	16.60 ^{abc}
Kervic F_1	61.00 ^{a}	32.67 ^{abcd}	1.67 ^{cd}	3.25 ^{c}	4.17 ^{bc}
Omdurman	47.00 ^{e}	48.67 ^{ab}	7.00 ^{bc}	58.97 ^{bc}	14.81 ^{abc}
Summerset	49.00 ^{de}	52.00 ^{a}	16.00 ^{a}	246.02 ^{a}	31.59 ^{a}
Mean	53.45	33.64	4.67	45.67	13.23

* Means followed by the same letter(s) within each column are not significantly different at $P \leq 0.05$, according to Duncan's multiple range test.

The number of fruits produced under open field conditions was observed to be zero in the heat sensitive genotype 'UC 82-B'. The heat tolerant genotype 'Summerset' produced the highest number of fruits. 'CLN-1-0-3' was intermediate, while the other genotypes produced low number of fruits per plant (Table 2).

Concerning fruit set percentage, there was a significant difference among the different genotypes (Table 2). 'Summerset' showed the highest fruit set percentage, while 'UC 82-B' the heat sensitive genotype produced no fruits. The other genotypes were low. 'CLN-1-0-3' was intermediate (Table 2).

For fruit fresh weight per plant, 'Summerset' had the highest fruit fresh weight per plant, while the other genotypes were either intermediate or low (Table 2).

4 Discussion

Temperature affects chemical reactions and physical properties of plants (Gruda, 2005). It was recognized that the response of generative growth to temperature varied considerably between glasshouse and field studies. These results were due to differences in the abiotic factors such as temperature, wind speed and light intensity as well as biotic factors like insects and diseases. As consequence, the relative stimulation of reproductive development of tomatoes in response to temperature in the current glasshouse was much larger than that observed under open field conditions.

4.1 Glasshouse experiment

According to Dorais *et al.* (2004) temperature is the most important climatic factor influencing sink strength and consequently photo-assimilate partitioning between plant organs.

There was a wide range of variation among the genotypes for the number of days to flowering and the number of flowers in this experiment. The difference may be attributed to genetic make of genotypes. Similar results were obtained by Lohar and Peat (1998) and Hussain *et al.* (2001).

'CLN-16B'and 'CLN-1-0-3' produced the highest number of fruits. But, there was no significant difference between the heat tolerant genotype 'Summerset' and the heat sensitive genotype 'UC 82-B'. Fruit set percentage showed the same trend as in the number of fruits per plant, 'CLN-16B' had the highest fruit set percentage, while 'Summerset', 'UC 82-B' and 'CLN-26D' were intermediate. This may be due to genetic factors (Hussain *et al.*, 2001). Fruit fresh weight per plant is not in line with the previous results of the number of fruits per plant, this may be due to the small size of the fruits of the genotypes that had the highest number of fruits per plant.

4.2 Field experiment

Prolonged periods of high temperature and hot dry wind under field conditions led to poor plant growth, deformities and abnormalities in flower structure during summer. In addition, excessive drying and browning of the stigma and style elongation were observed. These were probably responsible for the poor fruit set on most of the genotypes and lack of fruit set in the heat sensitive genotype 'UC 82-B' tested in this study. Satti and Abdalla (1984) and Dane *et al.* (1991) showed similar observations.

Consistent genotypic differences in sensitivity to high temperatures under field conditions were exemplified by the genotypes tested here for most of the characters. This confirms the early findings of Rainwater *et al.* (1996) who reported that different cultivars of tomato exhibited considerable variation in their sensitivity to heat stress.

Lohar and Peat (1998) reported that delays in flowering can lead to delays in fruit production. Thus, earlier flowering in heat tolerant genotypes as compared to the heat sensitive genotype can be considered as a good character for heat tolerance, as it enables heat tolerant genotypes to produce earlier crop. In addition, earliness can help in avoiding the problems associated with high temperature. In this study, the heat tolerant genotypes were earlier in flowering.

The number of flowers produced under field conditions was very low in most of the genotypes. Such effectiveness of high temperature is mainly due to the decrease in flower production and /or to bud and flower drop. This result falls in line with that of El-Ahmadi and Stevens (1979) who reported a similar finding wherein a heat sensitive genotype produced only aborted flowers at high temperature.

The number of fruits per plant and fruit set percentage was either low or completely lacking due to high temperature under open field conditions. 'Summerset' produced the highest number of fruits per plant, while 'UC 82-B' produced no fruit. Other genotypes were intermediate. This may be attributed to the genetic make of these genotypes (Hussain *et al.*, 2001). In addition, this is in accordance with the results obtained by Sato *et al.* (2004) who reported that the primary factor affecting fruit set under high temperature stress was the disruption of male reproductive development.

Fruit fresh weight in this study was more or less low and this can be attributed to the reduction in the fruit set. This result confirms earlier findings of El-Ahmadi and Stevens (1979), Sato *et al.* (2000) and Abdelmageed and Gruda (2009a).

The relative position of the flower on the plant is also important, as fruit set declines with time even under favorable conditions. Thus, flower abortion or lack thereof should not be used as the only indication of high temperature tolerance (Sato *et al.*, 2002). In addition, high temperature significantly increased the proportion of parthenocarpic fruit, undeveloped flowers, and aborted flowers. The primary factor affecting seeded fruit set under high elevated temperature stress in 'UC 82-B' was considered to be a disruption of male reproductive development (Sato *et al.*, 2002, 2004). Most of the genotypes grown under open field conditions during summer failed to give any significant economic yield. This marked reduction in yield may be attributed to diminished fruit set and fruit weight.

In conclusions, the heat tolerant genotypes offer opportunities as a genetic source of heat tolerance for breeding cultivars adapted to high temperature stress. They may also be useful in the study of the physiological basis of heat tolerance. In addition, according to this work and that from Hall (1992), it may be effective to screen for several morphological traits conferring heat tolerance. Furthermore, based on results obtained from this study, the genotype 'Summerset' proved to be high yielding under high temperature conditions in comparison to other genotypes.

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