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Performance of Different Tomato Genotypes in the Arid Tropics of Sudan during the Summer Season. I. Vegetative Growth

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Abstract

Selected, eleven tomato genotypes of diverse origin were grown in a glasshouse of the Humboldt University of Berlin, Germany during 2002 and under field conditions in Shambat, University of Khartoum, Sudan for two successive seasons (2002/2003, 2003/2004). High temperatures under field conditions resulted in poor stand and stunted growth of tomato plants. Highly significant differences were encountered among the different genotypes for leaf area, leaf area ratio, leaf weight ratio, stem fresh and dry weight and leaf fresh and dry weight. Based on results obtained from this study, the genotype 'Summerset' proved to be more tolerant under high temperature conditions in comparison to other investigated genotypes and may be useful for exploitation under arid tropical region of Sudan.

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

1 Introduction

Tomato is one of the major vegetable crops grown worldwide. Under open field conditions in arid regions like North Sudan, high temperatures ($\geq$ 35°C) can prevail for days and may extend into a portion of the dark period of the 24-h light-dark cycle (Abdalla and Verkerk, 1968). Heat stress adversely affects the vegetative growth and reproductive development of the tomato plants and ultimately reduces yield and fruit quality (Abdul-Baki, 1991).

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 winter.

Hall (1992) reported that the genetics and physiology of heat tolerance in reproductive tissues in many crops have received comparatively little attention, so 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. Because of such efforts, new varieties have enriched and advanced the horticulture of many countries. The productivity in vegetables depends upon plant growth that is greatly influenced by heat stress.

The objectives of this study were to investigate the effect of high temperature on tomatoes growth and to evaluate the different tomato genotypes for their response to high temperature under open field conditions during summer in Sudan. To have a full picture of the behavior of these genotypes, they were firstly evaluated under glasshouse conditions in Germany.

2 Materials and Methods

2.1 Glasshouse experiment

Eleven tomato genotypes with known differences in sensitivity to heat stress were used: 'CLN2413R' (tolerant), 'CLN2026D' (tolerant), 'CLN2116B' (tolerant) and 'CL5915-93D4-1-0-3'(tolerant) from Asian Vegetable Research and Development Center, (Taipai, Taiwan). 'Strain B (tolerant), 'Peto 86' (sensitive) and 'UC 82-B' (sensitive) from Peto Seed, Co. Inc (USA). 'Maverick F_1' (tolerant), 'Kervic F_1' (tolerant) and 'Drd 85 F_1' (tolerant) from De Ruiter Seed Company, the Netherlands. Summerset (tolerant) and Omdurman (tolerant) as local cultivars bred by the National Institute for Exports of Horticultural Crops, University of Gezira, Sudan.

They were evaluated 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. Tomato seeds were sown in flat trays filled with a standard peat mixture substrate for germination (C200) from Stender AG, Company, Germany. Substrate contained 0.5 g l^{-1} NPK fertilizer, had an electrical conductivity (EC) of 0.25 dS m^{-1} and a pH of 5.0-6.0. Fifteen days after sowing (DAS), the seedlings were transplanted into 9 cm containers filled with standard peat mixture substrate (C700) from the same company. Substrate contained 1 g l^{-1} NPK fertilizer, had an EC of 0.53 dS m^{-1} and pH 5.8. Tomato seedlings at 30 DAS were transferred into 14 cm diameter pots filled with same substrate. At 40 DAS the seedlings were transferred into Tube-like single-plant-pots 50 cm long by 25 cm diameter. The pots were closed in one end by perforated cover, which allowed free drainage of excess water. The pots had a volume of 8 l each and were filled with the same substrate (C700). Temperature and relative humidity were continuously recorded using hygrothermographs (Belfort Instrument, Baltimore, MD). Night temperature was 20-21 °C, and remained constant within this range, the maximum day temperature was 25-31 °C, with occasional days exceeding these limits. Relative humidity was 70-80%. The glasshouse conditions are referred herein as normal temperature. Tomato plants were watered every two days. Twice a week 40 ml of 0.2% soluble fertilizer (12% N – 4% P – 6% K) were applied to each pot.

The experiment was set up in a complete randomized block design with three replicates and with five plants for each genotype.

2.2 Field experiment

The same eleven genotypes used in the glasshouse experiment were cultivated under field conditions during summer in Sudan for two successive seasons. In the first season tomato seedlings were transplanted on 25 February 2003 and in the second season on 1 March 2004 to the experimental field of the Department of Horticulture Orchard, Faculty of Agriculture, University of Khartoum, Shambat, Sudan (Latitude 15° 40‘N and longitude 32° 32‘ E).

Tomato seeds were sown in trays filled with peat moss substrate imported from the Netherlands by Fresh Flower Company, Sudan. Four weeks old seedlings were hardened by direct exposure to sunlight for two weeks prior to field setting. Six weeks old seedlings were transplanted to the field on both sides of a flat ridge (bed) during late afternoon and irrigated immediately. The area of each plot was 4×4 meters during both seasons and each plot consisted of two flat ridges; spacing was 140 cm between rows and 40 cm between the plants along the row. The irrigation interval was every 5 days. All the necessary cultural practices and protection measures were adopted in the nursery and the field. The experiment was set up in a complete randomized block design with three replicates. Ten plants in each plot were randomly selected for data collection. OLIVER (1965) described the climate of Khartoum Province as arid tropical. The rainy season is between July and October, with a peak in August. The soil is a cracking heavy clay.

Monthly mean temperature and relative humidity were obtained from the meteorological station at Shambat (Table 1).

Table 1: Mean monthly temperature (°C) and relative humidity (RH %) during the experiment period.

Month	*2002/2003*				*2003/2004*			
	Temperature			*RH %*	*Temperature*			*RH %*
	Maximum	*Minimum*	*Mean*		*Maximum*	*Minimum*	*Mean*	
March	35.80	18.60	27.20	15	37.20	18.10	27.65	23
April	40.50	21.30	30.90	16	40.90	21.00	30.95	16
May	41.90	25.80	33.85	20	44.00	23.80	33.90	19
June	40.90	27.00	33.95	33	41.30	26.10	33.70	28
July	37.30	25.20	31.25	34	40.30	26.30	33.30	34

Source: Shambat Agrometeorological Station

2.3 Data collected

(1) Leaf area (cm^2): The leaf area was measured with an electronic leaf area meter, Type LI-COR Model 3100 (Lincoln, NE-USA) with a precision 0.01 cm^2.

(2) Stem fresh and dry weight (g $plant^{-1}$): Fresh weight of the stem was determined and then oven dried to a constant weight at 70 °C for a minimum of 72 h.

(3) Leaf fresh and dry weight (g $plant^{-1}$): Fresh weight of the stem was determined and then oven dried to a constant weight at 70 °C for a minimum of 72 h.

The following parameters were derived from the measured leaf area:

(4) Leaf area ratio (*LAR*) was calculated as leaf area divided by shoot dry weight for the glasshouse experiment and total plant dry weight for the field experiment according to RADFORD (1967).

(5) Specific leaf area (*SLA*) was calculated as leaf area divided by leaf dry weight according to RADFORD (1967).

(6) Leaf weight ratio (*LWR*) was calculated as leaf dry weight divided by shoot dry weight for the glasshouse experiment and total plant dry weight for the field experiment according to RADFORD (1967).

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 results under open field conditions are means of measurements for two seasons.

3.1 Glasshouse experiment

Concerning the glasshouse experiment, there was a wide range of variation among the different genotypes for leaf area. The heat tolerant genotype 'Summerset' had the highest leaf area, while the heat sensitive genotype 'UC 82-B' had the lowest value (Table 2). The other genotypes were intermediate.

Stem fresh and dry weight and leaf fresh and dry weight showed the same tendency. However, the genotype 'Drd 85 F_1' showed the bigger dry weight (Table 3).

LAR, *SLA* and *LWR* are presented in Table 2. 'Strain B' had the highest *LAR* compered to the other genotypes and 'CLN-16B' had the lowest one. Maximum *SLA* was found in the heat tolerant genotype 'Summerset' and the minimum values were obtained by 'CLN-16B' and 'UC 82-B'. There was a highly significant difference among the different genotypes for *LWR* (Table 2).

Table 2: Leaf area ratio (*LAR*), specific leaf area (*SLA*) and leaf weight ratio (*LWR*) of Diverse tomatoes grown under glasshouse conditions.

Genotype	*Leaf area (cm^2)*	*LAR (cm^2 g^{-1})*	*SLA (cm^2 g^{-1})*	*LWR (g g^{-1})*
CLN-1-0-3	7124.21 ^{b*}	104.39 ^{b}	191.83 ^{ab}	0.55 ^{def}
CLN-16B	5330.95 ^{c}	64.09 ^{c}	120.40 ^{d}	0.54 ^{def}
CLN-26D	5920.10 ^{bc}	91.03 ^{abc}	179.99 ^{abc}	0.53 ^{ef}
CLN-13R	5588.32 ^{bc}	76.81 ^{bc}	131.15 ^{cd}	0.59 ^{cde}
Strain B	6190.13 ^{bc}	111.55 ^{a}	166.38 ^{abcd}	0.67 ^{bc}
Maverick F_1	5916.98 ^{bc}	79.40 ^{bc}	128.19 ^{d}	0.62 ^{cd}
UC 82-B	3705.29 ^{d}	90.99 ^{abc}	120.90 ^{d}	0.75 ^{a}
Drd 85F_1	6504.13 ^{bc}	82.62 ^{abc}	139.09 ^{cd}	0.60 ^{cde}
Kervic F_1	6345.91 ^{bc}	86.94 ^{abc}	140.78 ^{cd}	0.62 ^{cd}
Omdurman	5190.05 ^{c}	91.59 ^{abc}	146.39 ^{bcd}	0.63 ^{c}
Summerset	8674.52 ^{a}	103.63 ^{ab}	210.38 ^{a}	0.49 ^{f}
Mean	6031.28	91.28	152.66	0.61

* Means followed by the same letter(s) within each column are not significantly different at the 5% level of probability according to Duncan's multiple range test.

Table 3: Stem fresh weight, stem dry weight, leaf fresh weight, and leaf dry weight of diverse tomatoes grown under glasshouse conditions.

Genotype	*Stem fresh wt (g)*	*Stem dry wt (g)*	*Leaf fresh wt (g)*	*Leaf dry wt (g)*
CLN-1-0-3	256.63 ^{ab*}	31.62 ^{abc}	289.98 ^{bcde}	36.92 ^{abc}
CLN-16B	263.33 ^{ab}	37.99 ^{ab}	313.28 ^{bcd}	45.27 ^{abc}
CLN-26D	213.61 ^{bc}	32.19 ^{abc}	314.35 ^{bcd}	35.32 ^{bc}
CLN-13R	259.59 ^{ab}	29.81 ^{bc}	322.03 ^{bc}	42.83 ^{abc}
Strain B	145.24 ^{de}	19.01 ^{d}	232.29 ^{ef}	38.27 ^{abc}
Maverick F_1	201.03 ^{c}	29.53 ^{bc}	310.46 ^{bcde}	47.05 ^{ab}
UC 82-B	79.68 ^{f}	11.18 ^{d}	190.47 ^{f}	33.26 ^{c}
Drd 85 F_1	216.26 ^{bc}	32.56 ^{abc}	335.69 ^{ab}	49.08 ^{a}
Kervic F_1	184.95 ^{cd}	28.98 ^{c}	312.43 ^{bcd}	47.16 ^{ab}
Omdurman	101.31 ^{ef}	28.30 ^{c}	258.94 ^{cde}	35.68 ^{abc}
Summerset	270.96 ^{a}	39.54 ^{a}	387.79 ^{a}	41.29 ^{abc}
Mean	191.57	27.98	293.30	40.82

* 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.

3.2 Field experiment

There was a significant difference among the genotypes for leaf area. The heat tolerant genotypes 'Summerset' and 'Omdurman' had the highest leaf area. 'Kervic F_1', 'UC -82-B', 'Strain B', and 'CLN -1-0-3' were intermediate, while the other genotypes had the lowest values (Table 4).

The differences in stem fresh and dry weights among the genotypes were highly significant. The heat tolerant genotypes 'Summerset' and 'Omdurman' exhibited the highest values for stem dry weight. 'Omdurman' exhibited an intermediate value for stem fresh weight, while 'CLN-16B' had the lowest value (Table 5). The same tendency was observed for leaf fresh and dry weight (Table 5).

For growth analysis parameters, there were highly significant differences among the genotypes for these parameters under field conditions (Table 4). 'CLN-1-0-3' had the highest *LAR*, while 'Maverick F_1' had the lowest value (Table 4).

Regarding *SLA* and *LWR*, 'CLN-1-0-3' showed the highest values. 'UC 82-B' exhibited the lowest values; the other genotypes were in between (Table 4).

Table 4: Leaf area ratio (*LAR*), specific leaf area (*SLA*) and leaf weight ratio (*LWR*) of diverse tomatoes grown under field conditions.

Genotype	*Leaf area (cm^2)*	*LAR (cm^2 g^{-1})*	*SLA (cm^2 g^{-1})*	*LWR (g g^{-1})*
CLN-1-0-3	935.39 ^{bc} *	104.77 ^{a}	173.66 ^{a}	0.64 ^{a}
CLN-16B	154.57 ^{c}	55.91 ^{bc}	158.85 ^{ab}	0.43 ^{b}
CLN-26D	513.83 ^{c}	80.30 ^{ab}	127.21 ^{abc}	0.63 ^{a}
CLN-13R	326.64 ^{c}	51.84 ^{bc}	93.83 ^{abc}	0.55 ^{ab}
Strain B	687.80 ^{bc}	49.13 ^{c}	75.80 ^{bc}	0.65 ^{a}
Maverick F_1	335.41 ^{c}	46.06 ^{c}	75.32 ^{bc}	0.62 ^{a}
UC 82-B	797.25 ^{bc}	47.54 ^{c}	72.51 ^{c}	0.67 ^{a}
Drd 85F_1	493.73 ^{c}	48.74 ^{c}	83.28 ^{bc}	0.59 ^{a}
Kervic F_1	826.02 ^{bc}	48.78 ^{c}	77.38 ^{bc}	0.63 ^{a}
Omdurman	1430.43 ^{ab}	49.48 ^{c}	76.20 ^{bc}	0.66 ^{a}
Summerset	2073.06 ^{a}	76.18 ^{bc}	140.04 ^{abc}	0.55 ^{ab}
Mean	779.47	59.88	104.92	0.60

* Means followed by the same letter(s) within each column are not significantly different at the 5% level of probability according to Duncan's multiple range test.

Table 5: Stem fresh weight, stem dry weight, leaf fresh weight, and leaf dry weight of diverse tomatoes grown under field conditions.

Genotype	*Stem fresh wt (g)*	*Stem dry wt (g)*	*Leaf fresh wt (g)*	*Leaf dry wt (g)*
CLN-1-0-3	27.08 ^{bc*}	3.28 ^{bc}	16.58 ^{b}	7.60 ^{bcd}
CLN-16B	4.76 ^{d}	1.53 ^{c}	3.11 ^{b}	1.27 ^{d}
CLN-26D	8.03 ^{cd}	2.39 ^{bc}	9.25 ^{b}	4.03 ^{cd}
CLN-13R	9.32 ^{cd}	2.62 ^{bc}	6.63 ^{b}	3.30 ^{cd}
Strain B	13.98 ^{cd}	4.54 ^{bc}	21.49 ^{b}	8.43 ^{bcd}
Maverick F_1	11.57 ^{cd}	2.77 ^{bc}	15.26 ^{b}	4.47 ^{cd}
UC 82-B	18.24 ^{bcd}	5.62 ^{b}	26.35 ^{b}	10.82 ^{bc}
Drd 85 F_1	12.68 ^{cd}	4.15 ^{bc}	13.37 ^{b}	5.86 ^{cd}
Kervic F_1	7.95 ^{cd}	4.75 ^{bc}	27.63 ^{b}	9.03 ^{bcd}
Omdurman	35.41 ^{b}	10.18 ^{a}	64.01a	15.08 ^{ab}
Summerset	65.33 ^{a}	12.28 ^{a}	77.52 ^{a}	19.03 ^{a}
Mean	19.48	4.92	25.57	8.08

* 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.

4 Discussion

The response of vegetative growth to temperature varied considerably between glasshouse and field studies. These results were due to differences in the environmental factors such as wind speed and light intensity, as well as biological factors like insects and diseases. As result, the relative stimulation in response to temperature in the current glasshouse was much larger than that observed under open field conditions.

4.1 Glasshouse experiment

In general, the different tomato genotypes that were grown under glasshouse conditions showed a vigorous vegetative growth compared to that grown under field conditions in Sudan. This might be due to the favorable environmental conditions encountered in the glasshouse.

Regarding the vegetative growth, there were some variations among the different genotypes. The heat tolerant genotype 'Summerset' had the highest leaf area, while the heat sensitive genotype 'UC 82-B' had the lowest. Also, stem fresh weight, stem dry weight and leaf fresh weight showed the same tendency. Thus, the heat tolerant genotype showed a higher rate of vegetative growth than the heat sensitive genotype. The difference may be attributed to the genetic make of these genotypes (Hussain *et al.*, 2001) and confirm the findings of Rainwater *et al.* (1996) who reported that different genotypes of tomato exhibited considerable variation in their sensitivity to heat stress.

4.2 Field experiment

High air temperatures combined with leaf curl disease during the growth period led to a poor stand and stunted growth on most of the cultivated genotypes. This is in agreement with earlier investigation. Infection by leaf curl was shown by YASSIN (1984) and GOMEZ *et al.* (2004) resulted in foliar curling and yellowing, reduced leaf area and plant stunting.

High temperature under open field conditions markedly decreased the leaf area of the plants. However, the heat tolerant genotype 'Summerset' showed the largest leaf area under open field conditions and 'UC 82-B' the lowest. The differences may be attributed to the genetic make of these genotypes. This result corroborates that of NKANSAH and ITO (1994) who found that heat tolerant cultivars had a higher leaf area than heat sensitive ones under high temperature conditions.

Further, high temperature and infection of the plants by leaf curl disease encountered under field conditions drastically reduced the stem fresh and dry weight as well as leaf fresh and dry weight of the different genotypes tested, which may be related to the depletion of reserve starch and other carbohydrates by respiratory losses due to high night temperature. Similar results were obtained by ABDELMAGEED and GRUDA (2007, 2009a). The authors reported that the higher the temperature, the lower the dry weight of the vegetative parts. In the present study, in agreement with results for leaf area, most of the heat tolerant genotypes demonstrated a better stem fresh and dry weight than the heat sensitive genotype 'UC 82-B'. This might be due to its ability to produce more carbohydrates than the heat sensitive genotype (NKANSAH and ITO, 1994).

In order to explain differences in growth between the heat tolerant and heat sensitive genotype, growth analysis was carried out. A high temperature under open field conditions significantly reduced the *LAR*, *SLA* and *LWR* for most of the genotypes. Leaf area ratio (*LAR*), is used in assessing effects of environmental conditions on the relative size of the assimilatory part (NKANSAH and ITO, 1994). The capacity of plants to accumulate dry matter depends to a large extent on the size of the leaf area to the overall size of the plant. In general, differences were found among the genotypes for the *LAR*, *SLA* and *LWR*. 'Summerset', a heat tolerant cultivar, had thicker leaves as compared to those of 'UC 82-B', a heat sensitive one. GOSSELIN and TRUDEL (1984) reported that the increase in shoot dry weight might have resulted from larger leaf areas and higher plant photosynthetic rates.

In general, growth analysis in this study indicated that greater partitioning might contribute to an improvement of crop productivity by increasing total carbohydrate production (NKANSAH and ITO, 1994).

Based on results obtained from this study, the genotype 'Summerset' proved to be more tolerant under high temperature conditions in comparison to other investigated genotypes. However, correlation analyzes between the vegetative and generative parameters need to be examined further.

The results for generative development will be presented in a second paper (ABDELMAGEED and GRUDA, 2009b).

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