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Effects of Temperature and Grafting on the Growth and Development of Tomato Plants under Controlled Conditions

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Abstract
Tomato (*Lycopersicon esculentum* Mill.) is a warm season vegetable crop with an optimum temperature for production of 28/22 °C (day/night). Heat stress is a major environmental stress that limits tomato production during summer under arid conditions. A variety of control measures and techniques including cultural practices in the field have been tested previously under Sudan conditions. Grafting of heat sensitive tomato cultivars could be used as scion, heat tolerant tomato or eggplant cultivars as rootstock to enhance heat tolerance into tomato plants.
The objective of this study is to examine if there is any positive effect of grafting on the vegetative and reproductive development in tomato plants under heat stress conditions.
The heat tolerant tomato cultivar 'Summer set' and the eggplant cultivar 'Black Beauty' as rootstock as well as the less heat tolerant tomato cultivar 'UC 82-B'as scion were selected. Plants were grown under two temperature regimes 30/22 °C and 38/27 °C (day/night) in plant growth chambers at the Department of Vegetable Crops, Institute for Horticultural Sciences, Faculty of Agriculture and Horticulture, Humboldt University of Berlin. The experiments were set up in a complete randomized design with five replicates for each treatment. The following characteristics were recorded: leaf area, fresh and dry weight of leaves and stem, fresh and dry weight of roots, number of clusters, number of flowers, and the number of pollen grains per microscopic field. In addition, chlorophyll fluorescence and electric conductivity were measured, suggested as a screening technique for heat tolerance.
Significant differences were encountered between treatment 'UC 82-B/Black Beauty' and 'UC 82-B' under 38/27 °C for chlorophyll fluorescence, electrolyte leakage and some vegetative and reproductive parameters. On the whole, grafting may have slightly positive effects on tomato vegetative growth and development under high temperature conditions.

Keywords: Arid conditions, heat stress, scion, rootstock, eggplant.

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important horticultural crops in the world, and that its production is very concentrated in semi-arid regions (Santa-Curz et al., 2002). In the Sudan the high temperatures during summer accompanied by low humidity limit the production of tomato to the cooler part of the year and leads to the seasonality of the crop production (Abdalla and Verkerk, 1968). Tomato production is limited by high day and night temperatures (Moore and Thomas, 1952). Dinar and Rudich (1985) reported that in tomato plants, high temperatures affect several physiological and biochemical processes dealing finally with yield reduction.

Overcoming heat stress problems will have a positive impact on tomato production. Several breeding programmes have been made to improve the heat tolerance of tomato, but with limited commercial success. One possibility to overcome this problem would be to graft the varieties onto rootstocks more efficient and capable of absorbing water, nutrient and high soil temperature tolerance.

Current applications of grafting include most fields of plant physiology for example, to induce disease resistance caused by soil pathogens, low temperature tolerance (Ahn et al., 1999), salt tolerance (Fernandez-Garcia et al., 2004), flood tolerance (Liao and Lin, 1996), drought tolerance (Iacono et al., 1998), to enhance nutrient and water uptake (Ruiz and Romero, 1999; Fernandez-Garcia et al., 2002) and high temperature tolerance (Abdelhafeez et al., 1975, Rivero et al., 2003a, 2003b).

According to Rivero et al., (2003a, 2003b) grafting of heat sensitive tomato cultivar onto more resistant rootstock cultivars would improve plants adaptation to heat stress conditions. However, there are only a limited number of reports on the effect of grafting on the heat stress in tomato plants.

The objective of this study is to examine if there is any positive effect of grafting on the vegetative and reproductive development in tomato plants under heat stress conditions.

Materials and Methods

The heat tolerant tomato cultivar ‘Summer set’ and the eggplant cultivar ‘Black Beauty’ were selected as rootstock and the less heat tolerant cultivar ‘UC 82-B’ as scion. They were sown in flat trays filled with standard peat mixture substrate for germination from Gramoflor Co., Germany. Substrate contains according to the producer company 50-300 mg/l N, 80-300 mg/l P_2O_4 and 80-400 mg/l K_2O fertilizer and had pH 5.0-6.5 ($CaCl_2$).

The eggplant Black Beauty was sown one week earlier than the two tomato cultivars. 15 days after sowing (DAS), the seedlings were transplanted into 9 cm pots filled with standard peat mixture substrate from the same company. The transplants were grown in the greenhouse of the Department of Vegetable Crops, Institute for Horticultural Sciences, Humboldt University of Berlin (Latitude 52° 30` N, Longitude 13° 25`E).

Tomato plants were watered daily. Twice a week 40 ml of 0.2% soluble fertilizer (12N-4P-6K) were applied to each pot. Twenty-two days after sowing, ‘UC 82-B’ was grafted onto the rootstock ‘Black Beauty’ and ‘Summer set’, using the pin-grafting method described by Lee et al. (1998). Specifically, grafting ceramic pins were used to hold the rootstocks and scion together tightly. Plants were covered by a transparent plastic film for 7 days in order to increase the relative humidity and to avoid dehydration by water loss.

Tomato plants at 35 DAS were transferred into 14 cm diameter pots filled with same substrate. 40 DAS the transplants were divided into two sets; one set was transferred in one plant growth chamber at 30/22 °C (day/night) for 13/11 h. Another set was transferred in a second plant growth chamber at 38/27 °C (day/night) for 13/11 h. On the day an irradiance of

550 µE $m^{-2}s^{-1}$ from a combination of fluorescent and incandescent lights lamps were provided for each set.

The experiments were set up in a complete randomized design with five replicates for each treatment. Plants were randomized within the plant growth chamber every week to avoid any potential positional effects.

The following parameters were recorded: Plant height (cm) from substrate surface to the vegetative point, leaf area (cm^2) with an electronic leaf area meter, Type LI-COR Model 3100 (Lincoln, NE-USA) with a precision ± 0.01 cm^2, fresh and dry weight of leaves (g $plant^{-1}$), as well as stem fresh and dry weight (g $plant^{-1}$).

Number of pollen grains per microscopic field was determined according to experiences of our previous experiments (Abdelmageed et al., 2003). In addition, electrolyte leakage and chlorophyll fluorescence were measured, suggested as a screening technique for heat tolerance. For the measurement of electrolyte leakage, leaves grown at two temperatures regimes were excised and washed with tap water. After drying with filter paper, 2 g fresh weight of leaves were cut into small pieces (about 2 cm^2) and placed in flasks with 60 ml deionized water. The flasks were shaken on a rotary shaker at 26 °C for 2 h (Ahn et al., 1999) and the electrolyte leakage diffused from the leaves tissues were measured using a conductivity meter (Digital conductivity meter, GmbH 3410, Greisinger Electronic, Germany). Chlorophyll fluorescence was measured a portable fluorometer (PAM 2000, Walz, Co., Effeltrich, Germany). The plants were dark adapted for 30 minutes before measurements of the chlorophyll fluorescence (Herde et al., 1999).

Data analysis

Collected data were analyzed using the SPSS statistical package software version 10.0. (Chicago, USA). One-way analysis of variance (ANOVA) was used to determine differences among treatments. Mean separation was done by Duncan's Multiple Range Test. In tables and figures, means with same letters indicate no significant differences between treatments at a probability level of 5%.

Results and Discussion

High temperature reduced the vegetative growth of the different plant treatments. However, the biomass production of plants come from grafting was higher than that from non-grafted plants (data not shown). Generally high temperature increases the chlorophyll fluorescence of all treatments except 'Summer set'. 'UC 82-B/Black Beauty' and 'UC 82-B/Summer set' had higher chlorophyll fluorescence than 'UC 82-B' at high temperature regime (38/27 °C) (data not shown).

Generally high temperature decreases the number of pollen grains produced and released by all tomato treatments. The number of pollen grains produced by 'UC82-B/Black Beauty' and 'Summer set' was higher than the numbers produced by 'UC 82-B' at high temperature regime (38/27 °C) (Fig. 1).

'UC 82-B/Black Beauty', 'UC 82-B/Summer set' and 'Summer set' showed lower electrolyte leakage compared to 'UC 82-B' under heat stress conditions, but no differences were shown between 'UC 82-B/ Summer set' and 'Summer set' (Fig. 2).

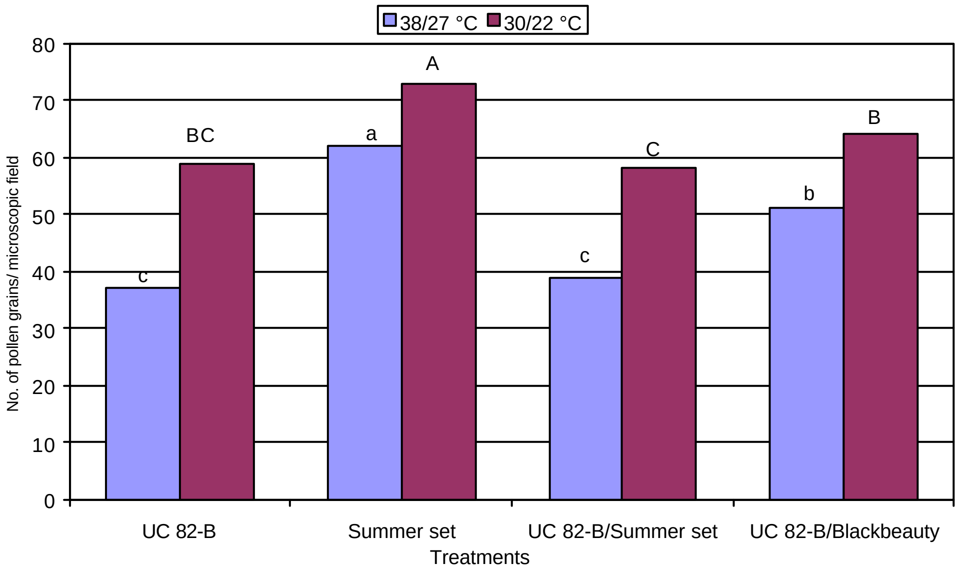

Fig. 1: Effect of temperature and grafting on number of pollen grains per microscopic field.
Differences between bars labeled by the same letters are not significant (P< 0.05)

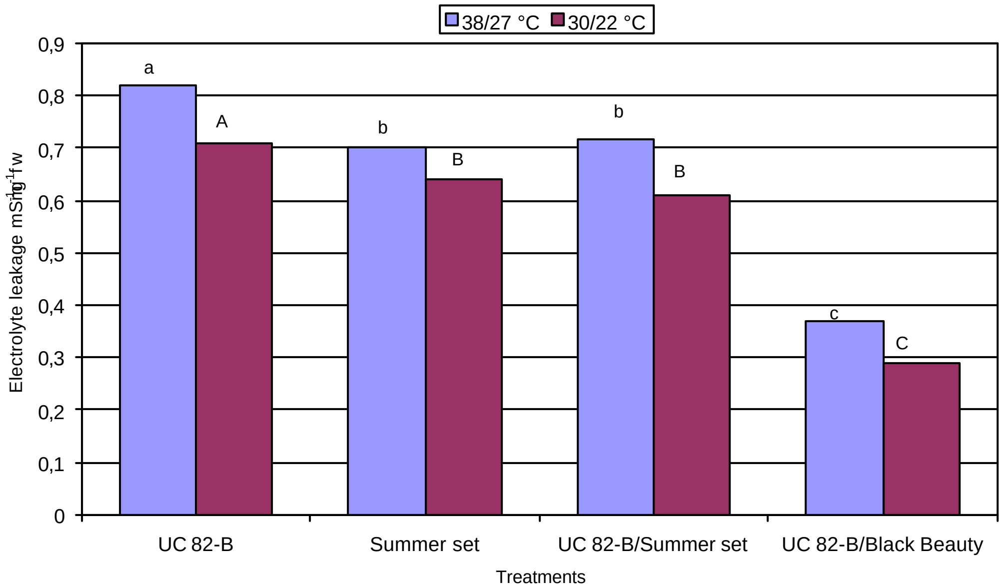

Fig. 2: Effect of temperature and grafting on electrolyte leakage.
Differences between bars labeled by the same letters are not significant (P< 0.05)

According to this experiments, grafting may have slightly positive effects on vegetative growth and development of tomato produced under high temperature conditions. The results of this study are in agreement with the results of Rivero et al. (2003a, 2003b) who mentioned that the effect of heat stress is much weaker in grafted than in non-grafted plants, where directly reflected in greater biomass production.

Further experiments under field conditions are needed to investigate the effect of grafting on tomato plants growth and development.

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