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Blossom-End Scar of Tomato Fruit Environmental Effects and Genetic Improvement

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Title

Blossom-end Scar of Tomato Fruit: Environmental Effects and Genetic
Improvement

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ABSTRACT

Rough blossom scars (RBS) were induced by treatment of seedlings with prolonged cool (17/12°C) temperature conditions but not by high temperature conditions. Nine days at 18/10° d/n induced RBS in flower primordia 19 to 23 days prior to anthesis. In a preliminary field experiment high winds induced RBS in flowers 5 to 7 days before anthesis. Style width was very highly correlated with blossom scar (BS) size ($r = .62$ to $.70$) over an array of 29 genotypes, whereas the style break point (height of abscission above ovary when style is bent) was not. Genotypes with the nipple (n) gene tended to have higher style breakpoints. Locule number was more highly correlated with BS than seed no. per gram of fruit for two genotypes ($r = .51$ to $.56$ vs $.26$ to $.49$ respectively). In a study of 21 genotypes, early fruit had greater RBS than later harvested fruit and BS size was highly correlated between early and late harvests. A correlation between fruit regularity (variation in equatorial dimension) and BS was not found. Auxin growth regulator (para-chlorophenoxyacetic acid) induced seedlessness and puffiness but not RBS under high temperatures in the field. Under cool field conditions, auxin growth regulators did not induce RBS in genotypes resistant to RBS. Ten parent half diallels in Fla. and Israel indicated no epistasis in inheritance of BS size. Both additive and dominance effects were significant but the former was much more important than the latter. Incomplete dominance was in the direction of small BS. Most genotypes were stable over locations but 'Suncoast' exhibited a strong interaction which resulted in a significant but small genotype x environment (G x E) interaction. Narrow sense heritability (h^2) based on single plots was $.6$ and $.7$ in Florida and Israel respectively. In a study of 27 genotypes in Israel h^2 was $.88$ to $.93$. In this study the G x E interaction was small but significant. In a study of 4 cultivars in 6 locations the stability slopes associated with the BS means.

OBJECTIVES

1. To elucidate the effects of environmental factors on blossom scar size and develop screening methods for improved blossom scar.
2. To determine if style breakpoint position, style width, or a combination of these factors are the main morphological factors affecting blossom scar size.

The above objective was studied and the variables did not prove to be highly correlated to blossom scar size (See Body section). Additional morphological factors such as seed number, locule number, fruit shape and fruit position on the plant were studied in relation to blossom scar size and will be reported under this objective.

3. Field screening of germplasm for improved blossom scar under high and low temperatures with and without application of growth hormones.
4. To conduct genetic investigations for estimation of genetic parameters controlling blossom scar size.

BODY OF REPORT

Many of the studies reported herein involve measurement of blossom scar size. The method generally used was called the blossom scar index (BSI-3) in the original proposal. BSI-3 for each fruit is calculated as follows:

$$\text{BSI-3} = \sqrt{\frac{a \times b}{c \times d}} \times 100$$

where a = longest diameter of the blossom scar
 b = shortest diameter of the blossom scar
 c = longest diameter of the median fruit cross section
 d = shortest diameter of the median fruit cross section

A. Environmental Effects

Previous studies (cited later in this section) indicated cool temperatures caused increased catfacing (rough blossom-end scar). Observations in Florida indicated catfacing is also prevalent early in the fall season under high temperatures. The first experiment described was done to see if rough blossom scars (RBS) could be induced by both low and high temperatures. The second experiment was an attempt to induce RBS by limiting fruit set under high temperatures. This is followed with a series of experiments designed to develop a cold temperature seedling treatment to determine the stage at which developing flowers are sensitive to cold and thereby provide a screening technique for breeding purposes.

TEMPERATURE EFFECTS ON BSI: SEEDING TREATMENTS

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The purpose of this experiment was to investigate the effects of high and of low temperatures during early stages of plant development on size of the blossom-end scar.

Materials and Methods

Seedlings were germinated at the Hebrew University, Rehovot, Israel and grown at 22/17, day/night temperatures, until the cotyledons reached full size (3/4/87 to 3/17/87). On March 18, they were transferred to phytotron-rooms of low (17/12), medium (22/17) and high (32/27) temperatures respectively. The five tomato lines in the experiment were:

BR54, a local F₁ hybrid
L830, cv. Suncoast
L836, cv. Hayslip
L880, a local breeding line
BR214, a local F₁ hybrid

Seven plants of each of the 5 tomato lines were grown in each phytotron chamber. The plants remained under their respective conditions until the first flower cluster became visible, and were then transplanted to uniform field conditions. The dates of transplanting varied with temperature conditions and were 4/10/87; 4/12/87; and 4/26/87, respectively.

An average of 3 fruits on each of first two clusters were harvested at the same date, when the fruits were full-sized but of different ripening stages, from green to red. BSI-3 was calculated for each.

Results

Figure 1 indicates the BSI of each variety and temperature treatment. High temperature caused increased BSI in cv L836 in comparison to 3 of the other cultivars which were not affected. The low temperature treatment resulted in

greatly and significantly increased BSI in 3 of the 5 lines (Fig. 1), but not in the "resistant" lines L880 and BR214 (Table 1).

Slight but inconsistent differences were also found between the first and the second fruit cluster. In the majority of treatments x cvs, BSI of the first flower cluster was slightly greater than in the second one.

Discussion

1. Genetic variation in BSI between the 5 tomato lines is expressed strongly when seedlings are developing under low temperatures. Under optimum temperatures of 22/17, differences between cvs are inconsistent. Thus, BR 54, characterized by the largest BSI under low temperature, has the smallest BSI at the control temperature.
2. Low temperature treatments applied to plants between cotyledon expansion and appearance of the first flower cluster resulted in greatly increased BSI in each of the first two fruit clusters of the 3 cvs BR54, L830 and L836, but not in L880 and BR214. The first 3 varieties are known for large blossom-end scars, the other two were bred for improved scars.
3. Somewhat unexpectedly, only L.836 (Hayslip) showed increased BSI as a result of high temperature treatment. But even for this line, the differences between high and medium temperature was not significant statistically.

Figure 1. Blossom-end scar index in tomato. Effect of varieties at three temperature regimes. LSD for all treatments ($P=0.05$). Different letters indicate significance between cvs within each temperature treatment (Duncan's Multiple Range Test, $p = 0.05$).

Table 1. Blossom-scar index (%) for cvs x temp. treatments. Treatments with identical letters are not significantly different (Duncan's multiple range test, p. 0.05*)

Temperature Day/night C	BR54	L830	Cultivar		
			L836	L880	BR214
17/22	^a A11.05	^b A8.70	^c A6.34	^d A2.63	^d AB2.09
22/17	^b B1.25	^{ab} B3.37	^{ab} B3.24	^{ab} A2.04	^a A3.69
32/27	^b B2.14	^{ab} B3.04	^a AB4.64	^b A1.39	^b B1.30

*Capital letters indicate difference between temperature treatments within each variety. Small letters indicate difference between varieties within each temperature treatment.

THE EFFECT OF GROWTH SPEED DURING EARLY FRUIT DEVELOPMENT ON SIZE OF BLOSSOM-END SCAR IN FULL-GROWN FRUITS GROWN UNDER HIGH TEMPERATURES

Introduction

Sikes and Coffey (1976) showed that pruning before fruit set resulted in fewer but larger fruits at early harvest and more blossom-end irregularities compared to unpruned treatments. When pruning was delayed until after fruit set, the fruits grew faster, but occurrence of blossom-end irregularities did not differ from unpruned treatments. An interpretation of these results can be that the critical stage at which growth speed influences blossom-end scar roughness is before anthesis in early flower development.

Results of experiments, conducted in the spring of 1988, showed that especially early, fast growing fruits are sensitive for blossom-end scar roughness. The hypothesis that fast growing fruits have an increased tendency for large blossom-end scars agrees with the assumption, that blossom-end irregularities may be caused by shortage of growth regulators at the stylar base in fast growing young fruits.

To test the proposed hypothesis, differences in growth speed of developing fruits were induced by flower pruning. Flower pruning was preferred over stem pruning, because the latter method may cause problems with secondary treatment effects, such as wind and temperature effects. The purpose of this experiment was to relate the differences in size of blossom-end scars in full-grown fruits to the growth speed in young developing flower buds. If a relationship is shown, it could indicate that the catfacing observed under high temperatures is due to limits on fruit set which result in fewer more rapidly growing fruit.

Materials and Methods

Six week old seedlings of six lines, known to have a good fruit set under Florida summer conditions, were planted in the field at Bradenton on 7/5/88.

The experiment consisted of a two factorial randomized complete block design with four replications, six genotypes, three pruning regimes and ten plants per plot.

When the flowers showed fruit set, i.e. about pea sized, they were tagged with the date. Thirty fruits in each plot were tagged and numbered from 7/29/88 to 8/22/88. Two weeks after fruit set, the fruit size of the tagged fruits was measured. The largest and smallest diameter of the median fruit cross section were averaged to obtain an estimate of the fruit size and this was an indication of the growth speed of the young fruits.

During tagging of fruit set, fruit pruning was started and maintained throughout the experiment. The three pruning regimes were as follows:

- 1) No fruit pruning
- 2) Pruning to three fruits per inflorescence
- 3) Pruning to one fruit per inflorescence

As soon as the desired number of fruits per inflorescence were set, the remaining flowers were pruned.

Fruits were harvested at the breaker stage on 9/2, 9/9, 9/14, 9/29 and 10/9 and measurements were taken to calculate BSI-3 for the tagged fruits in each plot and for about 20 more fruits per plot to obtain an accurate value for the BSI-3 of each plot. For ANOVA, the data were averaged per plot while data for individual fruits were used to calculate correlation coefficients. For each harvest, the fruits from each plot were graded, solely based on size of blossom-end scar. Thus number and weight of culls and number and weight of marketable fruits were recorded for each plot. For ANOVA, these data were summed over harvests.

Results and Discussion

The results of F-tests for genotype, pruning and interaction effects for several characteristics are in Table 1. A significant genotype effect was found

for all characters, except for total number of fruits per plot. This indicates, that the fruit set did not differ significantly between the lines used in this experiment. The parthenocarpic line, PAT-2, showed significantly smaller fruits, lower total yield, a significantly shorter ripening period and more fruits per plot than the other lines in the experiment (data not shown). For the average size of blossom-end scars (Table 1) and percentage of culls (data not shown), genotype Fla3046-1 had significantly larger values than the other lines in the experiment.

The pruning treatments did not result in any effects on the characteristics under investigation, except for the fruit size at harvest ($p\text{-val} < 0.05$; Table 1). Duncan's multiple range test showed that fruit size was significantly less for treatment 2 (pruning to three fruits per inflorescence), compared to the other two pruning treatments (data not shown). This is in contrast with what could be expected, i.e. smallest fruits resulting from treatment 1 (no flower pruning). Besides the fact that treatment effects were insignificant, average values per pruning treatment did not rank according to expectations for the other characters under investigation (data not shown).

Surprisingly, the average total number of fruits per plot did not show a significant pruning effect. Apparently, plants that were not pruned carried approximately the same amount of fruits as the ones that were pruned to one fruit per inflorescence. Fruit set may have been adversely affected by a heavy infection of bacterial spot (Xanthomonas campestris pv. vesicatoria). Thus the pruning treatments did not exert the desired effects.

Table 2 gives the correlation coefficients between growth speed in young fruits and size of blossom-end scars in full-grown fruits for six genotypes. Although the correlation coefficients were significant for two genotypes, the level of the coefficients was low. These low correlation coefficients may be

caused by the fact that differences in early growth speed were insignificant or that early growth speed as measured does not influence scar size in full-grown fruits. Analysis of the data for only early harvests, where BSI-3 was generally larger, did not result in conclusions different from those mentioned above.

The average BSI-3 per plot showed a high correlation with with the percentage of fruits that was discarded because of large blossom-end scars ($r = 0.89$; $n = 72$). This indicates, that a fast and efficient way to obtain a general impression of blossom-end scar roughness in a plot is grading the fruits as either cull or marketable, solely based on blossom-end scar size.

The experiment did not lend evidence to the hypothesis that catfacing occurs under high temperatures in Florida's fall crops because there is a lack of fruit set which results in few faster growing fruit. This could be due to the lack of desired pruning effect and this notion would have to be studied further.

Literature Cited

1. Sikes, J. and D. L. Coffey. 1976. Catfacing of tomato fruits as influenced by pruning. HortScience 11:26-27.

Table 1. F-tests for significance of line, pruning and their interaction effects on several characteristics, derived from the ANOVA analysis for a two factorial randomized complete block design, with four replications, six genotypes and three pruning regimes.

Characteristic	Line ¹ (d.f. = 5)		Pruning ² (d.f. = 2)		Line*pruning (d.f. = 10)	
	F-val	p-val	F-val	p-val	F-val	p-val
Early fruit size ^{3 4 5}	38.17	0.0001	3.08	0.0546	0.88	0.5572
Days until harvest ⁵	7.17	0.0001	2.01	0.1448	0.58	0.8265
BSI-3 ⁶	91.79	0.0001	0.87	0.4248	1.62	0.1285
Fruit size at harvest ^{4 6}	82.79	0.0001	3.83	0.0281	0.56	0.8354
Fruit weight at harvest ⁵	54.43	0.0001	1.86	0.1664	0.64	0.7706
Total number of fruits ⁷	1.06	0.3948	1.40	0.2552	0.50	0.8801
Percentage cull ⁷	63.93	0.0001	0.35	0.7062	0.33	0.9680
Yield ⁷	6.29	0.0001	1.11	0.3368	0.54	0.8539

¹The genotypes used in this experiment and their mean value for BSI-3 are:

genotype	avg BSI-3	DMRT
Fla3040-1	4.45	a
Fla3116-1	4.51	a
Solar Set	6.25	b
PAT-2 (parth)	6.40	b
Fla3031-SBK	6.58	b
Fla3046-1	9.80	c

²Pruning treatments:

- 1 No fruit pruning
- 2 Pruning to 3 fruits per inflorescence
- 3 Pruning to 1 fruit per inflorescence

³Fruit size 2 weeks after fruit set.

⁴Fruit size = $(a + b)/2$

with: a: largest diameter of median fruit cross section
b: shortest diameter of median fruit cross section

⁵Average per plot (over harvests) was based on ± 20 fruits.

⁷Average per plot (over harvests) was based on ± 40 fruits.

⁸Summed over harvests per plot.

Table 2. Spearman correlation coefficients for fruit size two weeks after fruit set with BSI-3 in full-grown fruits, based on data for individual fruits for six genotypes.

Genotype	n	Corr. coeff.	p-val. ($H_0:r=0$)
PAT-2 (parth)	204	0.037 ^{ns1}	0.5983
Fla. 3031-SBK	227	0.044 ^{ns}	0.5080
Fla. 3040-1	205	0.092 ^{ns}	0.1929
Solar Set	220	0.120 ^{ns}	0.0752
Fla. 3116-1	187	0.232**	0.0014
Fla. 3046-1	215	0.237***	0.0005

¹ns=not significant.

*=significant at 5% level.

**=significant at 1% level.

***=significant at 0.1% level.

THE EFFECT OF TEMPERATURES ON BLOSSOM-END SCARRING
1. Seedling induction in Florida, spring 1989

Introduction

The induction of rough blossom-end scars by means of long term low temperature treatments during seedling growth has been documented before (Kaname & Itagi, 1966; Knavel & Mohr, 1969; Sawhney & Polowick, 1985) and confirmed by Abel et al. (see first section of this report). High temperatures during seedling growth did not seem to influence blossom-end scarring (Sawhney & Polowick, 1985; Abel et al., final BARD report). To get a better understanding of the growth stage that is most sensitive to high or low temperatures, short term temperature treatments can be used. When studying the influence of low temperatures on locule proliferation, Saito and Ito (1971) found that short term cold treatment (17C/9C for 9 days) of seedlings at the 4 leaf stage induced increased locule numbers in fruit of the first inflorescence. A good correlation between the number of locules and blossom-end scar size was reported before (see our second annual BARD report). This experiment was conducted to study the effect of short term cold treatment during seedling growth on blossom-end scarring in mature fruits.

Materials and Methods

'Horizon' and 'Walter' were seeded at Bradenton on 2/22/89 and transplanted into 2"x2" seedling trays on 3/16/89 with empty cells surrounding each transplant. When the plants were at the 3 leaf stage (6 weeks old), the trays were moved into growth chambers and treated as follows:

- 1) Control, 6 days at 22C/17C.
- 2) 1 day at 22C/17C, 1 day at 10C/10C, 4 days at 22C/17C.
- 3) 1 day at 22C/17C, 3 days at 10C/10C, 2 days at 22C/17C.
- 4) 1 day at 22C/17C, 5 days at 10C/10C.

Of each treatment, 12 plants were planted in the field in a randomized complete block design (3 replications, 4 plants per plot) and 4 plants were potted in 12"

pots in a greenhouse in a completely randomized design (CRD). During the experiment, flowers were tagged at anthesis and 1235 mature fruits were harvested and number of locules and blossom-end scar index (BSI) were recorded. Due to mortality in the transplants and poor fruit set in the field and the greenhouse, low numbers of fruits had to be used in the analyses for some of the treatments (Table 2). The data for individual fruits were analyzed as an unbalanced CRD. Thus, in the field experiment, the block effects were incorporated into the error variation.

Results and Discussion

The treatment and genotype effects were analyzed, using the data for individual fruits pooled over anthesis dates (Table 1). Since all interaction effects were significant, treatment effects were analyzed per genotype using LSMEAN and CONTRAST statements in GLM procedure of SAS (Table 2). Except for the 3 day cold treatment of 'Walter' in the field experiment, no significant differences could be found between cold treatments for number of locules in mature fruits. In the field experiment, the average BSI was significantly different between cold treatments for 'Walter'. Note, however, that both the 1 day and 5 day cold treatment do not differ significantly from the control treatment. In the potted plants in the greenhouse, the difference in BSI between cold treatments was less pronounced than in the field experiment. Only for 'Horizon' did the 5 day cold treatment induce significantly greater BSI than the control. The data show that blossom-end roughness is better expressed when plants are grown in the field after an induction treatment. Apparently the relatively slow growth of potted greenhouse plants hampers the expression of rough blossom-end scarring. A relationship between growth dynamics and blossom-end scar expression has been reported before (Kaname & Itagi, 1966; Knavel & Mohr, 1969; Saito & Ito, 1971a; Sikes & Coffey, 1976; Wien & Minotti, 1988).

'Horizon' showed significantly larger BSI than 'Walter' in all treatments at the 5% level, except for the control treatment in the greenhouse experiment. The significance of treatment effects on BSI and number of locules was analyzed per anthesis date for each genotype separately. The results indicated that there is no particular growth stage that is most susceptible to cold treatments (data not shown).

The conclusion must be that the induction methods used in this experiment showed erratic results, depending on genotype and environment. Furthermore, no particular growth stage could be indicated as being susceptible to the cold treatments. In this experiment, the flowers were at 33 to 46 days before anthesis at the time of the cold treatment. It may be possible, that the flowers were not differentiating yet at that time. Undifferentiated flower buds have been found to be insensitive to low temperature treatments (Kaname & Itagi, 1966; Saito & Ito, 1971). The post-treatment growth dynamics seem to be important in promoting the expression of treatment effects.

Table 1. P-values for genotype, cold treatment and their interaction effects on blossom-end scar index (BSI) and number of locules in mature fruits (based on type III sums of squares in proc GLM).

Effect	BSI-3	Locule #
Field		
Genotype	0.0001	0.0001
Treatment	0.0004	0.0456
Genotype*treatment	0.0075	0.0017
Greenhouse		
Genotype	0.0001	0.0001
Treatment	0.1054	0.6987
Genotype*treatment	0.0310	0.0208

Table 2. Least squares means for blossom-end scar index (BSI-3) and number of locules in mature fruits for each temperature treatment per genotype.

Effect	Horizon			Walter		
	Fruit #	Avg BSI	Locule #	Fruit #	Avg BSI	Locule #
Field						
Control	54	12.29 a ¹	4.49 a	96	9.39 ac	5.54 a
1 day 10C	30	11.29 a	4.35 a	142	8.65 ab	5.61 a
3 days 10C	120	12.89 a	4.55 a	125	7.96 b	4.83 b
5 days 10C	178	13.09 a	4.47 a	243	9.64 c	5.29 a
Greenhouse						
Control	31	6.61 a	4.10 a	38	5.98 a	5.13 a
1 day 10C	26	7.72 ab	4.42 a	34	6.51 a	5.11 a
3 days 10C	27	7.62 ab	4.70 a	35	5.90 a	4.86 a
5 days 10C	19	8.59 b	4.21 a	37	5.65 a	5.27 a

¹Difference between temperature treatments within genotype is not significant at the 5% level of significance if followed by the same letter.

2. Induction in flowering plants, spring 1989, Florida

Introduction

The temperature effect on flowers at different stages of development was studied both in Israel (1988) and Florida (1989, 1990). Kaname and Itagi (1966) found that short term low temperature treatments only affected fruit quality when applied shortly before or after flower differentiation. Rylski (1979) reported that low temperature regimes induced catfacing before anthesis, but not after anthesis. Knavel and Mohr (1969) conclude the same from their histological studies. In Israelian studies, neither high or low temperature treatments (72 hours) caused increased blossom-end scarring in any of the developmental categories distinguished at the time of cold treatment (Second annual BARD report). The youngest category included young flower buds (up to 3 mm diameter). Studies in Florida were concentrated on short term low temperature treatments only to determine 1) if such treatments would be useful as a screening technique and 2) the stage at which developing fruits are sensitive to cold.

Materials and Methods

'Horizon' and 'Walter' were seeded on 1/19/89 and transplanted in 3.75² cm speedling trays on 1/27/89. The plants were potted in 15 cm pots on 3/10/89 and grown in a greenhouse until several flowers of the second inflorescence were at anthesis. The low temperature treatments and the experimental design were the same as those described in the previous experiment in the field and greenhouse. Flowers were tagged with their anthesis date from 8 days before to 23 days after the start of the cold treatments. Of 1610 mature fruits, blossom-end scar index (BSI-3) and number of locules were recorded (Table 1). Data for individual fruits were analyzed as an unbalanced CRD for field and greenhouse experiments.

Results and Discussion

Results of ANOVA for individual fruits pooled over anthesis dates are in

Table 2. None of the interaction effects were significant. Analysis of the main effects showed that locule numbers differed significantly between 'Horizon' and 'Walter'. The other main effects were not significant (Table 2). The expression of roughness in the greenhouse experiment was slightly less than in the field.

Fruit numbers in the greenhouse experiment were inadequate for analysis per anthesis date. In the field experiment, the temperature treatment effects were studied per anthesis date for each genotype separately. Because of low fruit numbers on most anthesis dates, developmental categories were made, each consisting of 3 consecutive anthesis dates. For each category, data for BSI and locule numbers were analyzed as an unbalanced CRD with temperature treatments as the only factor. The GLM procedure was used to calculate significance of the treatment effects and if significant, a multiple range test was conducted using the LSMEANS statement in proc GLM. The results are shown in Figures 1 to 4. Both 'Horizon' and 'Walter' show a significant temperature effect for flowers that were at anthesis 21 to 23 days after the start of the cold treatment. In both cases, 5 days at 10C caused significantly increased blossom-end roughness over the control treatment. Apparently, 3 days of cold treatment is not enough to induce increased blossom-end roughness as compared to control treatments. Flowers that were at 1 to 6 days past anthesis at the start of the cold treatment showed increased scarring for both 'Horizon' and 'Walter'. However, no significant difference between treatments was found. A possible explanation is, that all treatments experienced a cold period or another roughness-inducing condition before experimental treatments were started. Figure 5 shows that minimum night temperatures were low from 9 to 12 March. At this time the oldest flowers were at 21 to 25 days before anthesis. The plants were transplanted into 15 cm diameter pots on March 10, which may have amplified low temperature effects. The average number of locules did not follow the pattern for BSI

(Figures 2 and 4). In general, the older flowers showed increased locule numbers, coinciding with larger values for BSI. The increased values for BSI, induced by the cold treatment at 21 to 23 days before anthesis, however, did not coincide with significantly increased average number of locules.

In this experiment, two different lines of evidence show that flower primordia are most susceptible to low temperatures when they are at 21 to 25 days before anthesis. This coincides with the period that the flowers are differentiating (Saito & Ito, 1971). Kaname & Itagi (1966) and Saito & Ito (1971) found similar results for several fruit malformations and locule numbers, respectively. This new information can be used to develop a standard induction technique. More experiments are needed to further characterize the induction method and to eliminate confounding effects.

Table 1. Number of fruits in each treatment combination.

	Horizon	Walter
Field		
Control	176	185
1 day 10C	181	165
3 days 10C	175	169
5 days 10C	180	172
Greenhouse		
Control	23	25
1 day 10C	32	30
3 days 10C	25	23
5 days 10C	25	24

Table 2. P-values for genotype, cold treatment and their interaction effects on blossom-end scar index (BSI) and number of locules in mature fruits (based on type III sums of squares in poc GLM).

	BSI	Locule #
Field		
Genotype	0.2082	0.0001 ²
Treatment	0.0379 ¹	0.1567
Genotype*treatment	0.9549	0.4153
Greenhouse		
Genotype	0.4904	0.0001 ¹
Treatment	0.3399	0.5622
Genotype*treatment	0.7971	0.8015

¹The multiple range test did not show significant differences between treatments (data not shown).

²The least squares means for number of locules was significantly lower for 'Horizon' than for 'Walter' (4.22 vs 5.72 for field and 4.48 vs 5.70 for greenhouse).

- Figure 1. Average blossom-end scar index (BSI) for different temperature treatments per developmental category. The growth stage of the flowers in each category is indicated by the number of days before (<0) or after (>0) anthesis at the time the cold treatment started. Means indicated with different letters are significantly different at $\alpha=5\%$.
- Figure 2. Average number of locules for different temperature treatments per developmental category. The growth stage of the flowers in each category is indicated by the number of days before (<0) or after (>0) anthesis at the time the cold treatment started. Means indicated with different letters are significantly different at $\alpha=5\%$.
- Figure 3. Average blossom-end scar index (BSI) for different temperature treatments per developmental category. The growth stage of the flowers in each category is indicated by the number of days before (<0) or after (>0) anthesis at the time the cold treatment started. Means indicated with different letters are significantly different at $\alpha=5\%$.
- Figure 4. Average number of locules for different temperature treatments per developmental category. The growth stage of the flowers in each category is indicated by the number of days before (<0) or after (>0) anthesis at the time the cold treatment started. Means indicated with different letters are significantly different at $\alpha=5\%$.
- Figure 5. Maximum and minimum temperatures in March, 1989.

HORIZON

HORIZON

WALTER

WALTER

3. Induction in flowering plants

Introduction

In the previous experiment, low temperature treatments induced rough blossom-end scarring in flowers that were at 21 to 25 days before anthesis. The following experiments were done to further characterize the induction system by using different temperature regimes.

Materials and Methods

The cultivars Horizon and Solar Set, both known to be sensitive to rough blossom-end scar inducing factors, were seeded on 1/5/90, transplanted in 3.75x3.75 cm seedling trays on 1/17/90, potted in 7.5 cm diameter pots on 3/2/90 and transplanted to 15 cm diameter pots on 3/16/90. The plants were grown in a greenhouse until one or two flowers on the first inflorescence were at anthesis. Then the plants were transferred to growth chambers to undergo temperature treatments similar to those used by Saito and Ito (1971), i.e. 18C/10C for 0, 6 and 12 days. The following treatments were applied:

For 'Solar Set' (started on 3/28/90):

- 1) Greenhouse control, 12 days in greenhouse at ambient temperatures (Avg max: 32.5C, avg min: 18.5C) and daylight,
- 2) Control, 12 days in growth chamber at 29C/18C,
- 3) 6 days at 18C/10C, 6 days at 29C/18C,
- 4) 9 days at 18C/10C, 3 days at ambient temperatures in growth chamber.

A growth chamber malfunction interrupted the last treatment which was going to be 12 days long. For 'Horizon', treatments were started on 4/3/90 but due to the breakdown of the growth chamber during the experiment, treatments were unsatisfactory and 'Horizon' was eliminated from the experiment.

The greenhouse controls were included in the experiment to see whether the transition from greenhouse to growth chamber disturbs growth dynamics of

differentiating flower buds, leading to increased blossom-end scar roughness in all growth chamber treatments.

After the temperature treatments, 16 plants for each treatment were planted in greenhouse beds in a completely randomized design (CRD). The plants were grown in a greenhouse rather than the field to obtain more control over the post-treatment environment. Beds were used instead of pots, because the limited growth of potted plants may interfere with good expression of blossom-end scarring. Flowers were tagged with their anthesis date from several days before the start of the cold treatment to approximately 30 days after. Mature fruits were harvested and the blossom-end scar index (BSI-3) was recorded. Data for the individual fruits were analysed according to an unbalanced CRD.

Results and Discussion

The ANOVA for individual fruits pooled over anthesis dates showed that the treatment effect was significant (Table 1). Nine days of low temperature treatment significantly increased average BSI over the control treatments. Analysis per developmental category was needed to see whether this significant effect is due to sensitivity of a particular growth stage to low temperatures.

Fruit numbers were inadequate for analysis per anthesis date and developmental categories were made containing 5 consecutive anthesis dates. The GLM procedure was used to calculate significance of treatment effects within each category and if significant, a multiple range test was conducted using LSMEANS in proc GLM. The results indicated that flowers are sensitive to low temperature treatments 19 to 23 days before anthesis (Figure 1). In this developmental category, the average BSI did not differ significantly for the two control treatments, indicating that transfer of plants from greenhouse to growth chamber did not influence blossom-end scarring. Treatment 3 did not differ significantly from control treatment 2, which indicates that 6 days of cold

treatment did not cause significant induction of blossom-end scar roughness. Nine days of cold treatment (treatment 4) caused significantly increased values for BSI as compared to control treatment 2. Except for treatment effects, the graph is level over developmental stages, which means that no confounding effects played a role. Ambient temperatures in the greenhouse during seedling growth in February and March did not show a period with low temperatures like in March 1989.

The conclusion from this experiment is that flowers are susceptible to cold treatment at 19 to 23 days before anthesis, when the flowers are starting to differentiate. Nine days at 18C/10C was sufficient to induce increased scarring in 'Solar Set', while 6 days was too short. Saito and Ito (1971) found similar results for induction of increased locule numbers by short term low temperature treatments during seedling growth. The transition from greenhouse to growth chamber and post treatment growth in greenhouse beds did not interfere with the induction by cold treatment. This information is very useful in developing a standard screening procedure for rough blossom-end scarring. Information on susceptibility of different growth stages can be used to target observations when looking for an induction effect.

Literature Cited

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Table 1. Number of fruits and average blossom-end scar index (BSI) for different treatment combinations.

Treatment	'Solar Set'	
	Fruit #	Avg BSI
Control-greenhouse	140	6.15 a ²
Control-growth chamber	108	6.10 a
Treatment 3 ¹	138	6.62 a
Treatment 4 ¹	141	7.70 b

¹For specifics on treatments see text

²Means, followed by the same letter are not significantly different at $\alpha=5\%$

Figure 1. Effect of cold treatments on blossom scar size for different developmental stages of flower growth.

SOLAR SET

THE EFFECT OF FLORIDA SPRING WINDS ON THE SIZE OF BLOSSOM-END SCAR

Introduction

Among Florida growers, it is generally accepted that strong spring winds induce rough blossom-end scarring in tomatoes. An initial experiment in 1987 was conducted in a greenhouse using fans to simulate a wind event of 8 hours. That experiment failed to induce rough blossom scars due to either the growing conditions in pots, which are not conducive to expression of rough blossom scars, and/or ineffectiveness of the "wind" treatment. The purpose of this study was to investigate the influence of wind on blossom-end scar size in field grown tomatoes and determine the growth stage at which the flowers are most susceptible to wind damage.

Materials and Methods

Seven-week old seedlings of cv Horizon were planted in the field at Bradenton on 3/6/88. 'Horizon' is known to be sensitive for induction of large blossom-end scars. On 3/23/88, prior to flower anthesis, half of the plants were enclosed by 1.8 m³ nylon mesh cages to protect them from the wind. The experiment was a randomized complete block design with three replications, two treatments (cover and no cover) and six plants per plot. During windy periods, flowers at anthesis were tagged. High winds were recorded on 4/7/88, 4/12/88 and 4/18-19/88. The cages were removed on 5/13/88.

Full-grown fruits were harvested (5/25/88-6/18/88) and data needed to calculate BSI-3 were taken. Fruit regularity was rated on a 1 to 10 scale. From the experiment, 480 fruits were taken at random from both treatments during the first three harvests and number of locules and seeds were recorded. To study treatment effects, data for individual fruits were averaged per treatment and compared with t-tests. To elucidate growth stage effects, values for flowers

with the same anthesis date were averaged and treatments were compared with t-tests (Tables 1 and 2).

Results and Discussion

The microclimate inside the cages differed from the environment outside the cages. In uncovered treatments, the temperature rose faster in the morning and reached higher maximum values, compared to covered treatments. Uncovered treatments were also subjected to more small fluctuations in temperature. Humidity showed similar patterns within and outside the cages. Light intensity (photometric) inside the cages was approximately half the value for outside.

Blossom-end scars were significantly smaller in the caged plots (Table 1). As could be expected, fruits in caged plots took a significantly longer time to ripen, compared to uncovered plots. The fruits also showed decreased seed set when sheltered from the wind. Other studies (this report) indicated that decreased seed set correlated with larger blossom-end scars. However, in this experiment, protection from the wind significantly reduced the size of the scars. Because of secondary treatment effects, it is hard to separate the wind effect from other treatment effects.

A detailed overview of the interaction between treatments and anthesis date is in Table 2. Flowers at anthesis on 4/12-14 and 4/18-20 showed significantly larger blossom-end scars in uncovered plants, compared to covered ones. The last two registered winds (i.e. on 4/12 and 4/18-19) may have caused the increased blossom-end scar roughness in the uncovered plants. If so, this indicates that flowers are most sensitive for wind-induced blossom-end scarring from two days before anthesis to anthesis. Another possibility is, that the first wind storm (4/7) caused blossom-end scar roughness in fruits, that were at anthesis on 4/12-14 and the second wind on 4/12 caused the roughness from 4/18 to 4/20. If so, flowers are most susceptible from 7 to 5 days before anthesis. The treatment

effects on days to maturity and total number of seeds did not show interaction patterns that resembled those in Table 2. Thus the interaction pattern as shown in Table 2 can only be explained by wind effects.

Thus Florida spring winds appeared to induce rough blossom-end scars in tomato and flowers seem to be most sensitive to wind from either two days before anthesis to anthesis or 7 to 5 days before anthesis. These results agree with previous results, indicating that flowers are sensitive to low temperature effects sometime prior to anthesis (Kanamo & Itagi, 1966; Knavel & Mohr, 1969; Rylski, 1979). However, our results with seedlings indicate cold affects flowers 20-23 days before anthesis (see Temperature Experiments). Perhaps the sensitive stage for cold and wind effects are different. Of course, further work is needed to clarify the effects of wind on blossom scar size. These data provide some likely flower stages to look for an effect if one did a greenhouse test using fans. A follow-up field experiment was not successful due to a lack of a good wind storm. This points out the difficulty in conducting this type of work.

Literature Cited

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Table 1. F-tests for significance of treatment effects (d.f. = 1) on several fruit characteristics, derived from the ANOVA analyses for a randomized complete block design with three replications and two treatments (uncovered and covered).

Characteristic	F-val.	p-val.	Avg. for uncovered (n_1) ¹	Avg. for covered (n_2)
BSI-3	59.06 ^{***2}	0.0001	14.17 (931)	11.67 (631)
Days to maturity	52.98 ^{***}	0.0001	52.23 (521)	54.49 (408)
Total seed no.	4.36 ^{**}	0.0374	134.4 (331)	118.1 (148)
Fruit size ³	2.21 ^{ns}	0.1377	7.052 (931)	6.970 (631)
No. of locules	0.46 ^{ns}	0.4982	5.263 (331)	5.122 (148)
Regularity of shape ⁴	0.06 ^{ns}	0.8073	5.989 (923)	5.976 (627)

¹number of fruits for each characteristic is in parentheses.

²ns = not significant

* = significant at 5% level

** = significant at 1% level

*** = significant at 0.1% level

³Fruit size = $(a + b)/2$

with: a : largest diameter of median fruit cross section

b : shortest diameter of median fruit cross section

⁴Regularity of fruit shape was observed visually on a 1-10 scale with 10 for a perfect round fruit

Table 2. F-tests for significance of simple treatment effects at each anthesis date on size of blossom-end scar (BSI-3), derived from the ANOVA analysis for a two factorial randomized complete block design with three replications, two cover treatments and 15 anthesis dates.

Anthesis date	F-val.	p-val.	Avg. for uncovered	(n ₁)	Avg. for covered	(n ₂) ¹
6/4	0.04 ^{ns2}	0.8374	7.75	(8)	7.35	(5)
7/4 ^{o3}	0.09 ^{ns}	0.7601	8.03	(34)	7.62	(33)
8/4	0.09 ^{ns}	0.7600	11.05	(12)	11.96	(9)
9/4	0.76 ^{ns}	0.3844	16.02	(18)	18.03	(11)
10/4	2.86 ^{ns}	0.0912	17.33	(18)	13.76	(13)
11/4	2.40 ^{ns}	0.1217	19.18	(28)	16.37	(16)
12/4 ^o	13.39 ^{***}	0.0003	22.08	(64)	17.37	(33)
13/4	14.50 ^{***}	0.0001	18.16	(75)	14.78	(98)
14/4	6.44 [*]	0.0113	17.37	(26)	11.63	(11)
15/4	2.81 ^{ns}	0.0942	17.39	(23)	13.24	(8)
16/4	0.04 ^{ns}	0.8452	16.33	(20)	16.51	(11)
17/4	0.99 ^{ns}	0.3211	15.61	(37)	13.44	(16)
18/4 ^o	8.15 ^{**}	0.0044	14.46	(124)	12.13	(112)
19/4 ^o	4.66 [*]	0.0311	16.45	(14)	11.49	(15)
20/4	11.69 ^{***}	0.0007	17.09	(13)	9.43	(15)

¹n₁ number of fruits from uncovered plants

n₂ number of fruits from covered plants

²ns = not significant

* = significant at 5% level

** = significant at 1% level

*** = significant at 0.1% level

³o = spring winds were recorded on these dates

B. Morphology Associated With Blossom Scar Size

**THE RELATIONSHIP BETWEEN CERTAIN STYLAR CHARACTERISTICS AND
SIZE OF BLOSSOM-END SCAR IN TOMATO**

Introduction

Enlarged blossom-end scars affect appearance of tomato fruit and sometimes cause leakage of juice during storage of the fruit. Wide genetic variation in size of the blossom-end scar does exist. Criteria for early selection of plants with small blossom-end scar (BS) would enable breeders to treat large segregating populations. A relationship between stylar characteristics and size of BS has been assumed earlier (Fortney, 1959).

The present investigation is concerned with the feasibility of using, as selection criteria, the width of the style (W) and the height (H) of the breakage point of the style.

Materials and Methods

Cultivars and breeding lines were seeded on March 14, 1988 and planted at Rehovot on April 15 in a randomized block design with 2 replications and 4 plants per plot. For each of the 29 accessions, 32 flowers were collected at anthesis -4 from each plant- disregarding the first flower cluster of each plant. The flowers were kept in plastic vessels and brought to the lab, where petals, sepals and anthers were removed. Style measurements were made with accuracy of ± 0.02 mm by help of a binocular microscope. The stylar breakage point was assessed by carefully bending the style until breakage and measuring the distance from the breakage point to the basis of the style (=H, height). Stylar width (W) was measured at the stylar base.

The large and the small diameter of BS of each mature fruit was measured with a digital caliper with an accuracy of 0.02 mm. The geometric mean of the two measurements served as the measure of BSS in mm. The large and the small diameter of the equatorial cross section of the fruit was also measured and

their geometric mean served as a measure of fruit diameter (FRM). A blossom scar index (BSI), calculated by the formula $BSI = (BSS/FRC) \times 100$, represents BS in relation to fruit size.

Results

The relationship between the stylar breakage point H and width W to BS-size was investigated. Height of the stylar breakage point H ranged between 0.23 and 0.81 mm (Table 1). Lines with nipple tip (n gene) mostly reached the higher H values (Figures 1 and 2). Average stylar width W varied between 0.44 and 1.13 mm, with significant differences between lines (Table 2). Wide sense heritability for W and H were 0.6 and 0.3 respectively. This rough estimate is based on variety means and not on segregating F₂ populations.

Correlations between breakage point H, width W, stylar scar size (BSS,BSI) and fruit diameter FRM are given in Table 3. Correlation between H and all other criteria except FRM was low and not significant. However, there were significant correlations between stylar width W and each of the criteria fruit diameter (FRM) and scar size (BSS,BSI). The coefficients for genetic correlation between fruit diameter (FRM) and blossom-end scar (BSS,BSI) were low and not significant.

Discussion

It was the aim of the present investigation to find criteria for early selection of single plants in segregating populations, plants which should be characterized by small blossom-end scars. It is obvious from the low correlation coefficient, that height of stylar breakage points (H) cannot serve as one of the criteria for such a selection, in spite of preliminary results and literature indicating the contrary.

The style of a tomato flower is usually shedded or drying up some time after anthesis. The size of the resulting scar probably depends in part on stylar width, which explains the significant correlations between W and BSS or BSI.

Our results indicate, that early selection for small blossom-end scars, based on styler width, is possible. Selection according to the final size of the scar should give more exact results, but such an evaluation cannot be made at early stages of plant development.

Literature Cited

1. Fortney, W. R. 1959. Genetic and anatomical studies of imperfect styler scar formation in tomatoes. Ph.D. Thesis, Purdue University. 62 p.

Table 1. Height of stylar breakage point (H) and width (W) in 29 tomato accessions. (SE=standard error of mean).

Name	W		H	
	Mean	SE	Mean	SE
97-1	0.68	0.02	0.23	0.03
70T82-1	0.81	0.03	0.75	0.03
N-643	0.44	0.03	0.44	0.06
N-884	0.90	0.03	0.65	0.04
N-881	0.62	0.02	0.61	0.03
N-880	0.82	0.03	0.60	0.05
I5-F5-60-2	0.88	0.03	0.52	0.05
Y5-F5-246-1	1.00	0.04	0.48	0.04
FA-73	0.88	0.04	0.48	0.08
N-884	0.06	0.01	0.73	0.07
BR-214	0.68	0.03	0.69	0.02
NC-8276	0.85	0.04	0.48	0.03
NC-140	0.69	0.03	0.28	0.05
Bonanza	0.99	0.04	0.62	0.05
N-601	0.97	0.05	0.67	0.09
Y5-F6-235-b	0.90	0.05	0.52	0.07
BR-54	0.93	0.04	0.36	0.07
FA-75	0.88	0.07	0.54	0.10
FA-38	0.78	0.03	0.28	0.04
Duke	0.91	0.05	0.35	0.06
Hayslip	0.80	0.03	0.37	0.10
Horizon	0.93	0.03	0.30	0.06
N-888	0.97	0.03	0.57	0.04
Y5-F7-241-b	0.76	0.03	0.48	0.05
N-599	0.73	0.04	0.37	0.06
Suncoast	1.13	0.05	0.50	0.06
FA-67	0.96	0.04	0.81	0.06
BR-51	0.92	0.05	0.50	0.10
FA-47	0.90	0.03	0.70	0.07

Table 2. Analysis of variance for styler breakage point (H) and styler width (W) for 29 tomato accessions.

Source	d.f.	H		W	
		S.S.	P>F	S.S.	P>F
1. Genotype	28	20.5	0.0001	17.4	0.0001
2. Block	1	1.7	0.003	0.2	0.1
3. Genotype x Block	28	4.4	0.064	1.6	0.09
4. Plants within plot	171	17.8	0.32	6.9	0.97
5. Flowers within plant	670	66.2		34.5	

Table 3. Correlation coefficients between blossom-end scar size (BSS), scar index (BSI), fruit diameter (FRM), styler breakage point (H) and styler width (W) in 29 tomato accessions.

	W	H	BSS	BSI
FRM	0.73*** 0.02	0.55* 0.06	0.26 0.47**	0.14 0.32
BSI	0.62*** 0.32**	-0.24 0.13	0.99*** 0.97***	
BSS	0.70*** 0.29*	-0.13 0.11		
H	0.14 0.11			

upper value = genetic correlation

lower value = environmental

* ** *** indicate significance of 0.01, 0.001 and 0.0001 respectively.

Figure 1. Distribution of blossom-end scar size, BSS, of style breakage point, H, and of style width, W, in 29 tomato lines.

Figure 2. Correlation between scar size (BSS), style breakage point H (Fig.2a) and style width W (Fig.2b).

+ without nipple-tip * nipple-tip

THE RELATIONSHIP BETWEEN SIZE OF BLOSSOM-END SCAR AND SEED SET

I.

Introduction

In 1969, Knavel & Mohr proposed that blossom-end scar roughness may be caused by insufficient supply of growth regulators near the base of the style during critical stages of flower development. Presence of developing seeds may play a role in blossom-end scar development through their sink activity for growth regulators such as auxins (Varga & Bruinsma, 1976). This led to the hypothesis, that an increase in number of seeds might be associated with smaller blossom-end scars. To test the hypothesis, the relationship between blossom-end scar size and seed set in total fruit and in proximal and distal fruit halves was investigated.

Materials and Methods

Two genotypes were used for this study: NC8276, known for having small blossom-end scars, and Fla7132, usually exhibiting large blossom-end scars. From each genotype 240 full-grown fruits were harvested between May 31 and June 6, 1988 in Bradenton. For individual fruits, data were taken to calculate BSI-3 and the fruit was weighed. The fruit was cut in half equatorially and the number of locules were counted and the number of seeds in proximal and distal fruit halves were counted.

Results and Discussion

BSI-3 values for NC 8276 and Fla. 7132 were 5.492 and 15.370, respectively. Results (Table 1) show that the correlation between seed number in different fruit parts and BSI-3 improved when seed contents were measured relative to fruit fresh weight. Table 1 also shows that the correlation between number of locules and BSI-3 is significant and high. Fruits containing more locules show bigger scars.

The correlation between percentage of seed in the proximal fruit half and BSI-3 is negative (Table 1), indicating that an increase in proportion of seed in the distal part, near the blossom-end scar, is correlated with larger scars. This contradiction of the original hypothesis can be explained by a high positive correlation between total number of seeds and proportion of seed in the proximal fruit half ($r = 0.57-0.63$). A negative correlation between percentage of seeds in proximal fruit half and size of blossom-end scar may be the result of the negative correlation between total number of seeds and size of blossom-end scars. Thus, it can be argued, that the total number of seeds per unit fruit weight is the main factor influencing BSI-3 and the location within the fruit is not critical. An increase in total number of seeds is correlated with smaller blossom-end scars, supporting the hypothesis.

The conclusion is that the correlation between seed set and the size of blossom-end scars is genotype dependent and that the main factor is total number of seeds per unit fruit fresh weight. For both genotypes investigated, the correlation between number of locules and size of blossom-end scar was highly significant. Apparently, an increased number of locules causes a decrease in the ability of the ovary to close at the stylar end. A correlation between number of locules and BSI-3 has been suggested several times, but a direct correlation coefficient could not be found in the literature.

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2. Varga, A. and J. Bruinsma. 1976. Roles of seeds and auxins in tomato fruit growth. Z. Pflanzenphysiol. 80:95-104.

Table 1. Spearman correlation coefficients (r) for blossom scar size (BSI-3) with different fruit characteristics for two genotypes (n=240).

Characteristic	NC 8276		Fla. 7132	
	corr. coeff.	p-val. ($H_0:r=0$)	corr. coeff.	p-val. ($H_0:r=0$)
nrloc	0.513	0.0001	0.561	0.0001
nrprox	-0.201	0.0018	-0.365	0.0001
nrdist	-0.114	0.0783	-0.210	0.0011
nrtot	-0.158	0.0143	-0.297	0.0001
nrprox/fwt (gr^{-1})	-0.277	0.0001	-0.490	0.0001
nrdist/fwt (gr^{-1})	-0.221	0.0006	-0.422	0.0001
nrtot/fwt (gr^{-1})	-0.259	0.0001	-0.487	0.0001
nrprox/nrtot (%)	-0.263	0.0001	-0.385	0.0001

nrloc = number of locules in fruit

nrprox = number of seeds in proximal fruit half

nrdist = number of seeds in distal fruit half

nrtot = total number of seeds in fruit

fwt = fruit fresh weight

THE RELATIONSHIP BETWEEN SIZE OF BLOSSOM-END SCAR AND SEED SET II.

Introduction

Studies performed in 1988 indicated that the total number of seeds per unit fruit weight was negatively correlated with blossom-end scar size. The correlation coefficients were relatively low, which may have been caused by absence of extremely low values of seed set. A strong positive correlation ($r=.51$ to $.56$) between locule number and blossom-end scar size was found for the two genotypes involved. The present experiment was conducted to see whether dilution of pollen before self-pollination could reduce seed and/or locule numbers in mature fruits and thus influence the size of blossom-end scars.

Materials and Methods

The two genotypes used in this experiment, Solar Set and Horizon, are both known to be susceptible to blossom-end scar inducing factors. Two 5 plant plots of each variety were grown in the field in the spring of 1990. Flowers were emasculated and pollinated with a 100%, 50%, 10% or 5% pollen mixture with inert powder (Verkerk, 1957). Mature fruits were harvested, weighed and BSI-3 was measured. The number of seeds and locules were counted. Due to problems with fruit set, the 5% pollen mixture treatment was eliminated from the experiment. The data were analyzed as an unbalanced completely randomized design.

Results and Discussion

Although the fruit numbers were low (Table 1), some conclusions can be made (Tables 2 and 3). None of the interactions were significant. The dilution treatments had a significant effect on number of seeds per fruit and number of seeds per unit fruit weight. Pollen dilution had no significant effect on number of locules per fruit and size of the blossom-end scar. A dramatic difference in number of seeds per unit fruit weight between 100% and 10% pollen mixtures did not coincide with any difference in the size of the blossom-end scar (Table

2). Correlations between scar size and seed set were not significant (Table 4). The correlation between locule number and scar size was only significant for Horizon. One reason correlations were not significant could be due to low sample sizes. The actual coefficients were often not different than those of NC 8276 which were significant in the previous experiment. The results of both experiments indicate that seeds per fruit is not a major factor controlling (hormones which control) blossom scar size. Seed formation may influence the expression of blossom scar roughness under some conditions, especially in some genotypes, as indicated by the significant correlations. However, it is obvious there are other factors which account for a major portion of the variation for blossom scar size. The number of locules has some relationship to blossom scar size but again the correlations seen were inconsistent and not very high.

Literature Cited

1. Verkerk, K. 1957. The pollination of tomatoes. Netherland J. Agr. Sci. 5:37-54.

Table 1. Number of fruits for different treatments.

Treatment	Solar Set	Horizon
100% pollen	9	22
50% pollen	11	11
10% pollen	5	4

Table 2. P-values for genotype and pollen dilution effects and their interaction.

Characteristic	Genotype	Effect	
		Dilution	Interaction
No. seeds	0.0392	0.0002	0.2494
No. seeds/g fruit	0.0320	0.0009	0.2345
No. locules	0.0003	0.3701	0.9807
BSI-3	0.2354	0.9761	0.5612

Table 3. The least-squares means and multiple range comparisons¹ for the main effects in Table 2.

Characteristic	Genotype		Dilution		
	S.S.	Hor.	100%	50%	10%
No. seeds	90 a ²	60 b	114 a	77 b	33 c
No. of seeds/g fruit	0.69 a	0.43 b	0.86 a	0.54 b	0.29 b
No. locules	5.5 a	4.4 b	4.7 a	5.1 a	5.1 a
BSI-3	8.3 a	9.3 a	8.9 a	8.7 a	8.9 a

¹The 'CONTRAST' statement was used in proc GLM, because of unbalanced data set.

²Values in rows under genotype and dilution followed by the same letter are not significantly different at the $\alpha=0.05$ level of significance.

Table 4. The correlations between BSI-3 and different fruit characteristics for two genotypes.

Characteristics	Solar Set	Horizon
No. seeds ³	0.23 ^{ns1} (25) ²	0.22 ^{ns} (32)
No. seeds/g fruit ⁴	0.28 ^{ns} (25)	0.09 ^{ns} (32)
No. locules ⁴	0.03 ^{ns} (25)	0.39 [*] (37)

¹ns: not significant

^{*}: sign. at $\alpha=0.05$

²Number of fruits

³Pearson correlation coefficient

⁴Spearman correlation coefficient

GENETIC VARIATION IN SIZE OF BLOSSOM-END SCAR AND ITS EXPRESSION DURING EARLY AND LATE HARVESTS UNDER FLORIDA SPRING CONDITIONS

Introduction

A wide variation in size of blossom-end scar can be observed during Florida spring seasons. Field observations led to the impression that blossom-end scar roughness is more prominent in fruits harvested early in the season, compared to those harvested late in the season. The purpose of this experiment was to investigate genetic variation in blossom-end scar size during two different harvest periods (early vs. late).

Materials and Methods

Five-week old seedlings of 21 advanced lines were planted in the field at Bradenton on 2/28/88. The experimental design was a randomized complete block design with three replications, 21 genotypes and five plants per plot. During each of two harvests (5/31/88 and 6/18/88) 20 full-grown fruits were picked randomly from each plot. For individual fruits, data were taken to calculate BSI-3. BSI-3 for each genotype and harvest was averaged over the three replications and a Duncan's multiple range test was performed for both harvests (Tables 1 and 2).

Results and Discussion

During early, as well as late harvest, 'Valerie' performed better than the other genotypes investigated (Tables 1 and 2). 'Horizon', 'Suncoast' and 'Fla7132' exhibited relatively large blossom-end scars. The values of BSI-3 for the early harvest correlate well with those for the late harvest ($r = 0.733$; $n = 21$).

The general level of BSI-3 was significantly higher during the first harvest (t-test with $\sigma_{\text{early}}^2 \neq \sigma_{\text{late}}^2$; $\alpha = 1\%$). Also, the variance between genotypes was significantly higher for the first harvest (F-test; $\alpha = 5\%$), resulting in similar coefficients of variation for both harvests. The results indicate that

selection for small blossom-end scars can best be done early in the season, when both expression of BSI-3 and variance between lines are high. Early selection is justified by a strong correlation between early and late performance.

The coefficient of variation of BSI-3 per genotype was calculated for both harvests (Table 1 and 2). The tables show that genotypes with smaller scars did not have a smaller coefficient of variation. Especially inbred lines from the cross 'NC8276 x Suncoast' showed a high within-line coefficient of variation in the early harvest. Also, MH-1 showed much variation in BSI-3. For both harvests, the coefficient of variation was pooled over the genotypes ($CV_{\text{pooled}} = \sigma_{\text{pooled}} / \bar{x}_{\text{pooled}}$). The CV_{pooled} , an estimate for the environmental variability (Falconer, 1981), was significantly higher for the early harvest (sign test; $\alpha = 1\%$). Apparently, unknown factor(s) during early spring caused an increased expression of rough blossom-end scars.

Literature Cited

1. Falconer, D. S. 1981. Introduction to quantitative genetics. Second edition, Longman, NY. 340 pp.

Table 1. Blossom-end scar index (BSI-3) and coefficient of variation in BSI-3 for 21 genotypes during early harvest (5/31/88; n=60).

Genotype	BSI-3 ¹	DMRT ²	CV (%) ³
Valerie	5.077	A	64.2
P1061 Gardner	5.369	AB	33.0
NC8276	5.783	ABC	76.7
NC140	6.697	ABCD	65.6
Hor x (NC8276 x 7065) F ₆	7.595	ABCDE	83.0
Summit	8.051	ABCDE	69.7
(NC8276 x 7065)-BK-4-1	8.677	ABCDEF	96.5
Mt. Delight	8.854	BCDEF	33.4
Piedmont	9.214	CDEF	37.4
P1060 Gardner	9.699	DEFG	27.3
7155 x (NC8276 x 7065) F ₆	10.025	DEFGH	107.4
Hor x (NC8276 x 7065) F ₆	10.160	DEFGH	104.6
Fla7131	10.432	DEFGHI	57.5
Walter PF	10.842	EFGHI	49.9
MH-1	12.002	FGHI	104.6
Hor x (NC8276 x 7065) F ₆	12.033	FGHI	106.6
Fla7181	13.366	GHIJ	63.9
Suncoast (7065)	13.554	HIJ	58.0
Horizon	13.902	IJ	53.2
(NC8276 x 7065)-BK-18-1	14.061	IJ	84.4
Fla7132	16.087	J	57.1
	$\bar{x}$: 10.070	CV _{pooled} :	76.7
	s ² : 9.471		
	CV: 30.56%		

¹ANOVA indicated significant genotype effect, F-val.: 7.58, p-val.: 0.0001.

²Duncan's Multiple Range Test: Means followed by the same letter are not significantly different at 5% level of significance.

³Coefficient of Variation in BSI-3. ANOVA indicated significant genotype effect: F-val: 3.98, p-val.: 0.0001

Table 2. Blossom-end scar index (BSI-3) and coefficient of variation in BSI-3 for 21 genotypes during late harvest (6/18/88; n=60).

Genotype	BSI-3 ¹	DMRT ²	CV (%) ³
Valerie	3.104	A	45.0
Hor x (NC8276 x 7065) F ₆	3.451	AB	35.2
NC140	4.052	ABC	37.2
Hor x (NC8276 x 7065) F ₆	4.109	ABC	60.7
P1061 Gardner	4.227	ABCD	33.2
NC8276	4.301	ABCD	49.0
Hor x (NC8276 x 7065) F ₆	4.517	BCDE	45.3
7155 x (NC8276 x 7065) F ₆	5.068	CDE	42.5
(NC8276 x 7065)-BK-4-1	5.405	DEF	42.2
Fla7131	5.634	EFG	39.6
MH-1	5.692	EFG	63.1
Mt. Delight	6.352	FGH	47.2
Summit	6.526	FGH	54.8
(NC8276 x 7065)-BK-18-1	6.809	GH	63.0
Piedmont	7.234	HI	31.9
Walter PF	8.224	IJ	47.3
P1060 Gardner	8.248	IJ	41.4
Fla7181	8.489	JK	36.5
Horizon	8.747	JK	42.2
Fla7132	9.515	KL	45.4
Suncoast (7065)	10.239	L	61.4
$\bar{x}$:	6.188	CV _{pooled} :	50.4
s^2 :	4.392		
CV:	33.87%		

¹ANOVA indicated significant genotype effect, F-val.: 30.08, p-val.: 0.0001.

²Duncan's Multiple Range Test: Means followed by the same letter are not significantly different at 5% level of significance.

³Coefficient of Variation in BSI-3. ANOVA indicated an insignificant genotype effect (F-val: 1.81, p-val: 0.0550).

THE RELATIONSHIP BETWEEN REGULARITY OF FRUIT SHAPE AND SIZE OF THE BLOSSOM-END SCAR

Introduction

Field observations indicated that the blossom-end scar has a tendency to follow fruit shape and that irregularly shaped fruits tend to have larger scars. Furthermore, Sikes and Coffey (1976) suggested that uneven seed distribution within the fruit may be related to blossom-end irregularities. The purpose of this experiment was to elucidate the relationship between fruit regularity and size of blossom-end scar (BSI-3) for 21 genotypes. Also, the relationship between regularity of seed distribution over locules with BSI-3 was studied for 'Horizon'. The hypothesis is that irregularity in fruit shape and seed distribution may be related with increased size of blossom-end scars.

Materials and Methods

Twenty-one advanced lines were planted at Bradenton on February 28, 1988. At both harvests (5/31/88 and 6/18/88), 20 fruits were picked from each of the three replications per line. For individual fruit, measurements for BSI-3 were taken. Regularity of fruit shape was visually graded from 1-10, where perfect round fruits without any protruding locules would be graded 10. Also, regularity of fruit shape was calculated in two different ways:

$$\text{Regularity} = A - B \quad (\text{I})$$

$$\text{or Regularity} = A / B \quad (\text{II})$$

with A = largest diameter of median fruit cross section

B = shortest diameter of median fruit cross section

Formula I measures the irregularity in shape of full-grown fruits, while formula II is derived by taking the ratio of growth in two different directions.

Several plots of Horizon were planted in the field on 3/6/88. During three harvest periods (5/25/88, 5/30/88 and 6/5/88) a total of 480 fruits were harvested. For each fruit, data needed to calculate BSI-3 were taken and

regularity (1-10) was scored. Individual fruits were cut in half and the number of locules, total number of seeds and number of seeds for each locule were scored. For each fruit the coefficient of variation for number of seeds per locule was calculated and used as a parameter to indicate regularity of seed distribution over locules.

Results and Discussion

Significance of the correlation coefficient for BSI-3 with regularity of fruit shape differed considerably between genotypes (Table 1). Only eight genotypes showed a correlation coefficient that was significantly different from 0 at the 1% level of significance. For one of these genotypes ('Valerie') the correlation coefficient was opposite of what was expected. T-tests indicated that genotypes with a highly significant negative correlation between regularity of fruit shape and BSI-3 did not show a higher or lower general level of blossom-end scar size or fruit shape regularity, compared with the other genotypes in this study (data not shown).

The two methods to derive regularity of fruit shape from largest and shortest diameter of median fruit cross sections (formulas I & II) generally showed a fair correlation with visually assessed fruit regularity (varying from .25-.52). However, the correlations between BSI-3 and two formulas used to calculate regularity showed similar variation between genotypes as those observed using the visual rating in Table 1.

Table 2 shows the absence of a linear relationship between regularity of seed distribution over locules and size of blossom-end scars. Generally, fruits with many seeds showed a more regular distribution of seeds over locules. The correlation between regularity of fruit shape and variation of seed distribution over locules was only moderate. Variation in size of locules was not evaluated, but may play a role in relationships mentioned above.

The linear correlation between BSI-3 and either visual or objective assessment of fruit regularity strongly differed between genotypes. A linear relationship between regularity of seed distribution and BSI-3 could not be found. The results indicate insufficient evidence that regularity in fruit shape and seed distribution are associated with blossom-end scar roughness, although fruit shape may play a role in blossom-end roughness in some genotypes.

Literature Cited

1. Sikes, J. and D. L. Coffey. 1976. Catfacing of tomato fruits as influenced by pruning. HortScience 11:26-27.

Table 1. Blossom-end scar index (BSI-3), regularity of fruit shape (assessed visually, 1-10, with 10 for a perfect round fruit) and Spearman rank correlation coefficients for BSI-3 with fruit regularity for each genotype (n = 120).

Genotype	Avg. BSI-3	Avg. reg.	Corr. coeff.	p-val. ($H_0:r=0$)
Valerie	4.09	6.05	0.25*	0.0060
Horizon	11.32	6.03	0.08	0.4026
Fla7131	8.03	6.43	0.06	0.5444
Mt. Delight	7.60	7.20	0.00	0.9767
P1061 Gardner	4.80	6.92	-0.01	0.9037
P1060 Gardner	8.97	6.51	-0.03	0.7044
(HORx(NC8276x7065)F ₆)	6.81	6.00	-0.06	0.5505
(HORx(NC8276x7065)F ₆)	5.85	6.16	-0.07	0.4433
Fla7181	10.93	6.34	-0.14	0.1327
Piedmont	8.22	7.12	-0.15	0.1129
MH-1	8.85	6.00	-0.16	0.0871
NC8276	5.04	6.30	-0.18	0.0486
Walter PF	9.53	6.06	-0.19	0.0410
Summit	7.29	6.58	-0.19	0.0358
(HORx(NC8276x7065)F ₆)	8.27	5.98	-0.24*	0.0072
NC140	5.37	6.70	-0.25*	0.0050
Suncoast (7065)	11.90	6.17	-0.35*	0.0001
(NC8276x7065)-BK-4-1	7.04	6.30	-0.37*	0.0001
Fla7132	12.80	6.20	-0.37*	0.0001
(7155x(NC8276x7065)F ₆)	7.55	5.08	-0.51*	0.0001
(NC8276x7065)-BK-18-1	10.44	5.58	-0.70*	0.0001

* significant at 1% level

Table 2. Spearman rank correlation coefficients (r) for several fruit characters with coefficient of variation for seed distribution over locules (n = 480).

Fruit character	Corr. coeff.	p-val. ($H_0:r=0$)
BSI-3	0.097	0.0334
Regularity of shape	-0.179	0.0001
Fruit size ¹	-0.180	0.0001
Number of locules	0.111	0.0154
Total seed number	-0.512	0.0001

¹Fruit size = (a + b)/2 with: a: largest diameter of median fruit cross section

b: shortest diameter of median fruit cross section

C. Field Screening of Germplasm

Some of the initial experiments of the project were involved with field screening of arrays of germplasm to find the best resistance to blossom-end scarring. An experiment was conducted before the project in Florida during N. Kedar's sabbatical leave. This experiment provided a test of BSI-3 and also verified several genotypes with small and large blossom scar. Two subsequent experiments are described in this section of the report. The first verified some genotypes with good blossom scars grown under Israeli winter (cool) conditions without auxin hormones. The second experiment tested the effects of an auxin growth regulator on various genotypes under high temperature conditions in Florida. The effects of an auxin growth regulator on blossom scar size under Israeli winter conditions was assayed in the diallel experiment described in the Genetic Investigations section. The field screening tests provided insight into genotypes to use in the diallel study and subsequently which would most likely result in the breeding line release(s) with smooth blossom scar. Evaluation of the breeding lines is presently underway and will be done after this final report.

GENETIC VARIATION IN SIZE OF BLOSSOM-END SCAR UNDER LOW TEMPERATURES

S. Widefsky, R. Aker and N. Kedar

It is well known that the problem of increased blossom end scars (BS) is very serious under low temperature conditions (Rylski, 1979). Genetic variation in the reaction of tomato lines for blossom scar size had not been studied earlier. The present experiment was a first attempt to investigate BSI (BS-Index) under natural winter conditions in Israel.

Materials and Methods

Location and Climate. Ejn Tamar, Arava, Negev. Figure 1 indicates maximum and minimum temperature averages for 10 day periods during Nov., Dec. and January 1986/87. The experiment included 30 tomato lines planted in a completely randomized design with 4 replicates of 8 plants per plot. Five-week old plants in seedling units were planted on October 25, 1986. Mature-green and pink fruits - 25 of each replicate - were harvested on Jan. 25, 1985. A total of 100 fruits of each line was brought to the lab and BSI-3 was calculated. Duncan's multiple range test was employed to check significance between lines.

Results

BSI-3 values for the 30 lines varied greatly and significantly. Seven partly overlapping groups could be distinguished (Table 1). Varieties with the greatest blossom-end scar originated in Florida, those with the smallest BS were derived from the cv Valerie. Other Florida and Israeli lines or hybrids ranged inbetween the two extreme types, with significant differences between them.

The existence of genetic variation in BSI under normal outdoor conditions during early winter has been shown. Promising new breeding lines will be released after further testing.

Literature Cited

1. Rylski, Irena. 1979. Effect of temperatures and growth regulators on fruit malformation in tomato. *Scientia Horticulturae* 10:27-35.

Table 1. Blossom scar index (BSI-3) for genetic lines grown in cool temperatures in Ejn Tamar, Arava, Negev Israel

Genotype	BSI-3
Horizon (#840)	8.799 a ^z
Duke (#704)	8.482 a
Suncoast (#830)	7.937 ab
#601	7.934 ab
FL 7132 (#839)	7.908 ab
FA 67	7.768 abc
FA 75	6.926 abcd
BR 51	6.909 abcd
#40	5.732 bcde
FL 7131 (#832)	5.417 cdef
#234	5.252 cdef
BR 54	5.081 cdef
#888	5.065 cdef
Hayslip (#836)	4.933 cdef
FA 73	4.889 cdef
#599	4.860 cdef
Y-5-F5-256-1	4.703 def
FA 38	4.293 efg
#643	4.241 efg
E101 BK	4.196 efg
Bonanza (#757)	4.028 efg
#36	3.910 efg
#887	3.337 efg
Y-5-F6-235-B	3.241 efg
#880	3.157 efg
Y-5-F9-241-B	3.139 efg
#884	3.127 efg
I-5-F4-60-2	2.838 fg
#881	2.008 g
BR 214	1.893 g

^zMean separation in column by Duncan's multiple range test.

Figure 1. Maximum and minimum temperatures in the Ejn Tamar area in the Southern Negev during November and December 1986 and January 1987. (Each point gives the average of a 10 day period).

THE EFFECT OF GROWTH REGULATORS ON FRUIT SET, YIELD AND FRUIT QUALITY IN TOMATO UNDER SUMMER CONDITIONS IN FLORIDA

Introduction

In Israel, growth regulators are frequently used to improve fruit set under cold winter conditions. Rylski (1979) found, that low temperatures as well as growth regulators caused fruit deformations such as rough blossom-end scarring, puffiness and seedlessness. The purpose of this experiment was to investigate the effect of auxins on fruit set and fruit quality under Florida summer conditions. At high temperatures, the fertility of young tomato flowers decreases drastically (Varga & Bruinsma, 1986), leading to fruit set problems in many cultivars in Florida.

Materials and Methods

Seedlings of 14 genotypes were planted in the field at Bradenton on 7/5/88, when they were six weeks old. Four of the 14 genotypes used in this experiment are known to yield well under Florida summer conditions. The genotypes used in this experiment were (HT: heat tolerant, HS heat sensitive):

Fla 7169	HT
Fla 7171	HT
Fla 873031-SBK	HT
Solar Set	HT
Fla 7060	HS
MH-1	HS
Valerie	HS
Fla-1B	HS
P1060 Gardner	HS
P1061 Gardner	HS
Suncoast	HS
Horizon	HS
Fla 7182	HS
Fla 7181	HS

Two months after field planting, growth regulator applications were initiated. 'Tomato Set', with active ingredient para-chlorophenoxyacetic acid (PCA) was sprayed onto fully flowering inflorescences using an atomizer. Each inflorescence was sprayed only once. 'Tomato Set' treatments were maintained

throughout the experiment. The experiment was conducted in a replicated split-plot design with two treatments (growth regulator and water) as the main-plot factor, 14 genotypes as the sub-plot factor and 7 plants per plot.

During three harvests (9/13/88, 9/20/88 and 9/27/88), fruits at breaker stage or beyond were harvested and graded as either marketable or cull, solely based on blossom-end scar size. For each plot, number and weight of culls and marketable fruits were recorded, as well as number of puffy and seedless fruits. ANOVA's were conducted for data, summed over harvests, and for data separated by harvests. Contrast procedures were used to compare the treatment effects for the HT genotypes with those for the HS ones (Table 2).

Results and Discussion

The effect of the growth regulator application on five fruit characteristics is in Table 1. The data indicate that treatment with the growth regulator enhanced earliness. For the first harvest the number of fruits and total yield significantly increased with application of the growth regulator. In the third harvest, fruit set and yield was better in the plots without the growth regulator treatment, resulting in a non significant effect on pooled fruit set and yield per plot (Table 1). The application of 'Tomato Set' did not significantly increase the occurrence of rough blossom-end scarring, however a profound effect on the presence of puffy and seedless fruits was found. Occurrence of both puffy and seedless fruits increased dramatically with the application of 'Tomato Set' (Table 1). Incidence of fruit irregularities, such as rough blossom-end scarring, puffiness and seedlessness decreased during the growing season. ANOVA's indicated that the genotype effects were highly significant (at the 0.1% level) for the five traits mentioned in table 1 (data not shown). Percentage of puffy fruits did not show a significant genotype effect in the first two harvests. Line*treatment interactions were

insignificant, except for percentage seedless fruit in the first harvest, where the line*treatment interaction was significant at the 0.1% level (data not shown).

Although line*treatment interactions were mostly insignificant, the effects of application of the growth regulator may differ between HT and HS genotypes. In Table 2, the treatment effects on HT genotypes are compared with those on HS genotypes. Table 2 shows that for HT as well as for HS genotypes, treatment with 'Tomato Set' increased the number of fruits harvested in the first harvest. This increase in fruit set was more significant for HS than for HT genotypes. Yield for both HT and HS genotypes increased significantly for the first harvest. Application of 'Tomato Set' caused decreased fruit set in later (second and third) harvests for HT as well as HS genotypes. This decrease in fruit set coincided with a highly significant decrease in yield for the third harvest. Growth regulator application did not significantly influence total yield and fruit set for either HT or HS genotypes. These results show the same tendencies as those mentioned in table 1. Maybe high early production (caused by growth regulators) exhausted the nutrient supplies, resulting in decreased yield later in the growing season. Note that the fruit set and yield were very low, especially for the HS genotypes (Table 2). Adverse weather conditions and an epidemic of bacterial spot (Xanthomonas campestris pv. vesicatoria) during the summer growing season contributed to this poor performance. Considering yield and fruit set, the HT genotypes performed better than the HS ones at all harvests and both treatments (Table 2). The contrasts were generally significant at the 0.1% level (data not shown).

The occurrence of fruit irregularities was also studied for HT and HS genotypes separately. Application of the growth regulator did not significantly increase the occurrence of blossom-end scars for any of the harvests or class of

genotypes (data not shown). Comparison of HT with HS genotypes showed a lower occurrence of blossom-end scars in the HT genotypes used in this experiment (data not shown). For some treatment and harvest combinations this difference was significant at the 5% level. Table 2 shows, that application of 'Tomato Set' greatly increased the occurrence of puffy fruits, especially in HS genotypes. Rylski, 1979 also found auxin growth regulator caused some puffiness in some genotypes under low temperatures. HT genotypes had less puffy fruits than HS genotypes for all harvests and treatments (Table 2), however, none of these contrasts were significant at the 5% level (data not shown). The experiment exhibited a wide variation in occurrence of seedless fruits. Untreated plots with HT genotypes yielded almost no seedless fruits, while HS genotypes treated with 'Tomato Set' exhibited a very high occurrence of seedless fruits, especially in the first harvest. The percentage of seedless fruit generally was significantly greater with growth regulator treatment. This was also the case under low temperature conditions (Rylski, 1979). The occurrence of seedless fruits was higher for the HS genotypes, than for the HT ones (Table 2). These contrasts were not significant at the 5% level for untreated plots, however, for plots treated with 'Tomato Set' the contrasts between HT and HS genotypes were significant at the 5% level.

The conclusion of this experiment is that 'Tomato Set' enhances early fruit set of HT as well as HS genotypes. However, the total yield over a growing season does not increase with application of the growth regulator. 'Tomato Set' does not influence the occurrence of rough blossom-end scars, however, it increases puffiness and seedlessness. HT genotypes are less sensitive for puffiness and seedlessness than HS genotypes. Thus, if economically feasible, growth regulator can be applied to enhance early production. It is recommended

that HT genotypes be grown because of their higher yield and lower sensitivity for fruit irregularities.

Literature Cited

1. Rylski, I. 1979. Effect of temperatures and growth regulators on fruit malformation in tomato. Sci. Hort. 10:27-35.
2. Varga, A. and J. Bruinsma. 1986. Tomato. In: Handbook of fruit set and development, Monselise, S.P. Ed. CRC Press, Boca Raton, Florida, pp. 461-481.

Table 1. Values for several characteristics averaged over genotypes for untreated plots vs plots treated with 'tomato set' for several harvests and pooled over harvests (seven plants per plot).

Treatment	Harvest 1 (9/13)	Harvest 2 (9/20)	Harvest 3 (9/27)	Pooled
Number of fruits per plot (n=42) ¹				
Water ²	7.88 a ³	21.45 a	29.29 a	58.62 a
Tomato set	12.43 b	15.60 a	18.91 b	46.93 a
Yield (kg) per plot (n=42)				
Water	2.75 a	7.50 a	9.94 a	20.19 a
Tomato set	5.84 b	6.64 a	7.43 b	19.90 a
Percentage cull per plot ⁴ /number of plots				
Water	37.19/31 a	25.49/41 a	14.34/42 a	20.64/42 a
Tomato set	31.64/42 a	25.01/41 a	12.40/42 a	22.22/42 a
Percentage puffy per plot/number of plots				
Water	14.11/31 a	8.72/41 a	4.93/42 a	7.70/42 a
Tomato set	37.99/42 b	20.72/41 b	11.17/42 b	21.35/42 b
Percentage seedless per plot/number of plots				
Water	6.11/31 a	4.43/41 a	2.75/42 a	3.96/42 a
Tomato set	82.17/42 b	37.01/41 b	15.35/42 b	41.07/42 b

¹Number of plots

²Water was used as control.

³Duncan's Multiple Range Test, means followed by the same letter are not significantly different at the 5% level of significance.

⁴The fruits were sorted as either cull or marketable, solely based on the size of the blossom-end scar.

Table 2. F-tests for the significance of the effect of treatment with 'tomato set' on several characteristics for heat tolerant (HT) and heat sensitive (HS) genotypes for several harvests and pooled over harvests (seven plants per plot).

Geno- type	Harvest	F-val.	p-val.	Avg for untreated (n) ¹ plots	Avg for treated (n) plots
Number of fruits per plot					
HT	9/13	0.97 ^{ns2}	0.3300	14.42 (12)	17.92 (12)
	9/20	2.18 ^{ns}	0.1455	41.83 (12)	33.17 (12)
	9/27	3.39 ^{ns}	0.0712	53.25 (12)	37.83 (12)
	Pooled	1.69 ^{ns}	0.1990	109.50 (12)	88.92 (12)
HS	9/13	4.87*	0.0318	5.27 (30)	10.23 (30)
	9/20	1.63 ^{ns}	0.2076	13.30 (30)	8.57 (30)
	9/27	2.50 ^{ns}	0.1200	19.70 (30)	11.33 (30)
	Pooled	0.66 ^{ns}	0.4201	38.27 (30)	30.13 (30)
Yield (kg) per plot					
HT	9/13	13.21***	0.0006	5.32 (12)	8.13 (12)
	9/20	0.75 ^{ns}	0.3911	14.68 (12)	13.82 (12)
	9/27	8.15**	0.0062	16.57 (12)	13.03 (12)
	Pooled	0.74 ^{ns}	0.3938	36.58 (12)	34.99 (12)
HS	9/13	42.96***	0.0001	1.71 (30)	4.92 (30)
	9/20	1.92 ^{ns}	0.1717	4.62 (30)	3.76 (30)
	9/27	7.16**	0.0099	7.29 (30)	5.19 (30)
	Pooled	0.04 ^{ns}	0.8428	13.63 (30)	13.87 (30)
Percent puffy fruits per plot					
HT	9/13	7.22*	0.0105	9.72 (12)	35.25 (12)
	9/20	1.58 ^{ns}	0.2147	5.41 (12)	15.57 (12)
	9/27	0.37 ^{ns}	0.5473	3.35 (12)	6.00 (12)
	Pooled	5.45*	0.0234	4.82 (12)	15.19 (12)
HS	9/13 ³	6.82*	0.0126	16.89 (19)	35.84 (27)
	9/20	7.17**	0.0100	10.09 (29)	22.85 (29)
	9/27	7.73**	0.0075	5.57 (30)	13.24 (30)
	Pooled	28.39***	0.0001	8.86 (30)	23.82 (30)
Percent seedless fruits per plot					
HT	9/13	134.02***	0.0001	4.23 (12)	56.18 (12)
	9/20	22.31***	0.0001	0.43 (12)	28.45 (12)
	9/27	0.71 ^{ns}	0.4025	0.10 (12)	6.06 (12)
	Pooled	16.28***	0.0002	0.73 (12)	24.02 (12)
HS	9/13 ³	510.78***	0.0001	6.21 (19)	91.73 (27)
	9/20	77.93***	0.0001	6.08 (29)	40.56 (29)
	9/27	11.66**	0.0012	3.81 (30)	19.06 (30)
	Pooled	136.49***	0.0001	5.25 (30)	47.89 (30)

¹n = number of plots.

²ns = not significant.

* = significant at 5% level.

** = significant at 1% level.

*** = significant at 0.1% level.

³Genotype Fla 7181 was not included in the analysis.

D. Genetic Investigations of Blossom Scar Size

This section is comprised of 3 studies. The former two are papers which have been accepted for publication in Euphytica. The last is a paper presently being locally reviewed for eventual publication in a refereed journal.

DESCRIPTION OF COOPERATION

Cooperation started before the project officially began when N. Kedar did his sabbatical at Bradenton and conducted 5 experiments on blossom-end scar. Israeli germplasm was tested in Florida and Florida germplasm was taken to Israel. The Florida germplasm was used in several of the experiments conducted in Israel. In March 1987, J. W. Scott traveled to Israel to meet J. Elkind and the Israeli students working on the project. Numerous discussions were held with this group, along with N. Kedar, regarding the BARD research and other tomato breeding topics. The trip also afforded J. W. Scott the opportunity to meet several scientists at the Faculty of Agriculture at Rehovot and at the Volcani Institute and present a seminar on Florida Tomato Breeding. Since the trip, communication was established by computer via BITNET which allows rapid transfer of data and other information. We have exchanged F_2 seed of selections made in our respective countries for testing and advancement for eventual breeding line release(s). The 3 principal investigators met at the Tomato Breeders Roundtable in San Diego, California in March 1988 and exchanged ideas and results.

In 1989, advanced breeding lines with smooth blossom scars selected in each country were exchanged for final testing which is presently underway. This should result in breeding line release(s). J. Elkind wrote two papers which were edited by J. W. Scott and J. Barten (Ph.D. student) in the U.S. Both have been accepted for publication. Diallel data from Israel was shipped to the U.S. for joint analysis. This paper will be submitted for publication in the Fall 1990.

EVALUATION OF THE RESEARCH ACHIEVEMENTS AND BENEFITS TO AGRICULTURE

Although rough blossom scars are a major cause of cull fruit production in Israel, the United States and many other countries, at the time of this project there was virtually no scientific literature on the subject. Herein is a brief description of the progress we made in this unexplored field.

Environmental Effects

The existing literature did report greater catfacing (blossom scar roughness) was caused by cool temperatures. This was confirmed by our work, but not in all experiments. No one had identified the stage of flower development sensitive to cold. By using relatively short cold treatments, 9 da at 18/10°C, and monitoring anthesis dates we found the sensitive stage to be about 19-25 days before anthesis. Quite probably this technique could be used to screen germplasm as the breeder would know what flowers to look at to select for blossom scar smoothness. Beyond this, scientists wishing to determine the anatomical or physiological reasons for rough blossom scar now have a technique for conducting these studies.

The proposal called for testing the effects of high temperature on blossom scar. We were unable to detect such an effect and our results do not permit definitive conclusions. Catfacing does occur under high temperatures in the field, but the heat may cause this indirectly by limiting fruit set. We were unable to demonstrate this, but can not refute it either. Otherwise, there is a condition where tomatoes develop multiple styles with channels between them that usually are surrounded by a necrotic ring of tissue. This is prevalent under high temperatures in the field but was not studied under controlled conditions due to emphasis on the cold treatments.

Several experiments attempted to study the possible effect of wind on blossom scar size. This is a very difficult area of experimentation. The first

step was to demonstrate an effect under field conditions. An experiment did point to a wind effect in flowers which were 5 to 7 days before anthesis during the wind. Further experimentation is needed to verify this, but this work does provide a likely target to find such an effect. This could lead to controllable treatments with fans which could eventually lead to discovery of why there is an effect. Perhaps it is not the wind itself but a chill factor, etc. Much of our work points out difficulty in obtaining expression of rough blossom scars when plants are grown in pots. This information should be helpful in the design of future experiments.

Morphological Factors.

Before the project, there was some evidence that the point of stylar abscission could be an early selectable marker for smooth blossom scar. Our work detected little correlation of the style break point with blossom scar size. The technique may have some use in certain genetic backgrounds, but is not an easy indicator of scar size. Style width was a better indicator over a diverse array of genotypes. Several other factors were studied to determine if they were associated with blossom scar size. Several reviewers of the proposal thought cold induced less seed formation which in turn resulted in rough scars. We were unable to detect a strong relationship between seed number and blossom scar size. Thus, seed may play a role in blossom scar size but other factors seem more critical. The morphological work should allow for future work to proceed along other avenues since no highly correlated characteristics were found.

There are several genes such as nipple tip (n) which effect blossom-end morphology and might be useful in reducing blossom scar size. In work being carried out in Florida after this report, several such genes are being tested for complementation. Hopefully this work will provide breeders with a clear idea of what genes are available to them for breeding for smooth blossom scars. This

should provide a sound basis for efficient cultivar improvement in the future. The intent is to publish this work and a copy should be found in the publication section.

Field Screening of Germplasm

Arrays of genotypes were tested under diverse environmental conditions. Generally, genotypes resistant to blossom scars under one environment were also resistant under other environments. Genotypes with medium or rough scars followed a similar trend overall. This testing allowed for selection of an array of parents for the diallel and likely F_1 's to advance and select for breeding line release. Advanced testing of lines for release is presently underway in Israel and the U.S. When released, the breeding lines should provide useful, adaptable germplasm for cultivar development in the U.S. and Israel.

This work demonstrated certain genotypes are well suited to auxin growth regulator treatments under low and high temperatures. Hormones are being used under cool conditions in Israel. These results will be helpful in selection of lines adaptable to such conditions. The use of hormones in Florida to stimulate fruit set under high temperatures has not been done commercially. Our results indicate no problem with blossom scar but further work is needed to elucidate possible problems with puffiness.

Genetic Studies

There was no information on the genetics of blossom scar size in tomato until this project. The type of information derived was close to that envisioned in the original proposal and is a major portion of the project. This genetic information (given elsewhere) will provide a solid foundation for breeders and should improve breeding efficiency. Luckily the results are quite favorable for genetic improvement. The diallel analysis over 2 completely different environments is probably unprecedented in horticultural crops and shows the

potential of quantitative analyses in horticultural crops. Using the analyses of Hayman and Allard, the often only theoretically approached genetic parameters could actually be used to identify a major gene effect in 'Suncoast' which was different between the 2 locations. To our knowledge, this is the first time quantitative methods for diallel analysis could be used in such a proficient way.

In summary, advances were made in understanding both environmental and genetic control of blossom end scarring. In the short run, this information should provide for improved breeding methodology and more efficient cultivar development. This will be especially true with the release of breeding lines with smooth blossom scar. Agricultural tomato production will benefit. In the long run, information derived provides a foundation for future research progress in genetic, anatomical, morphological, or physiological aspects of fruit formation in tomato and perhaps other crops.

LIST OF PUBLICATIONS

1. Scott, J. W., J. Barten, N. Kedar, and J. Elkind. 1989. Environmental and genetic investigation of blossom-end scar of tomato. Proc. Tomato Breeders Roundtable, Culiacan, Sinaloa, Mexico, pp. 9-10. (Abstr.).
2. Elkind, Yonatan, Ofra Bar-Oz Galper, Jay W. Scott and Nachum Kedar. 1990. Genotype by environment interaction of tomato blossom-end scar size. Euphytica (in press).
3. Elkind, Yonatan, Ofra Bar-Oz Galper, Shroga Vidavski, Jay W. Scott and Nachum Kedar. 1990. Genetic variation and heritability of blossom-end scar size in tomato. Euphytica (in press).
4. Barten, J. H. M., J. W. Scott, J. Elkind, and N. Kedar. 1990. Diallel analysis of rough blossom-end scarring in tomato. HortScience 25: in press. (Abstr.).

NOTE: A refereed publication of #4 above is in preparation and will likely be submitted to the Journal of the American Society for Horticultural Science. Other work in connection with the grant is still proceeding and further publications are anticipated. Breeding line release(s) will appear in HortScience.