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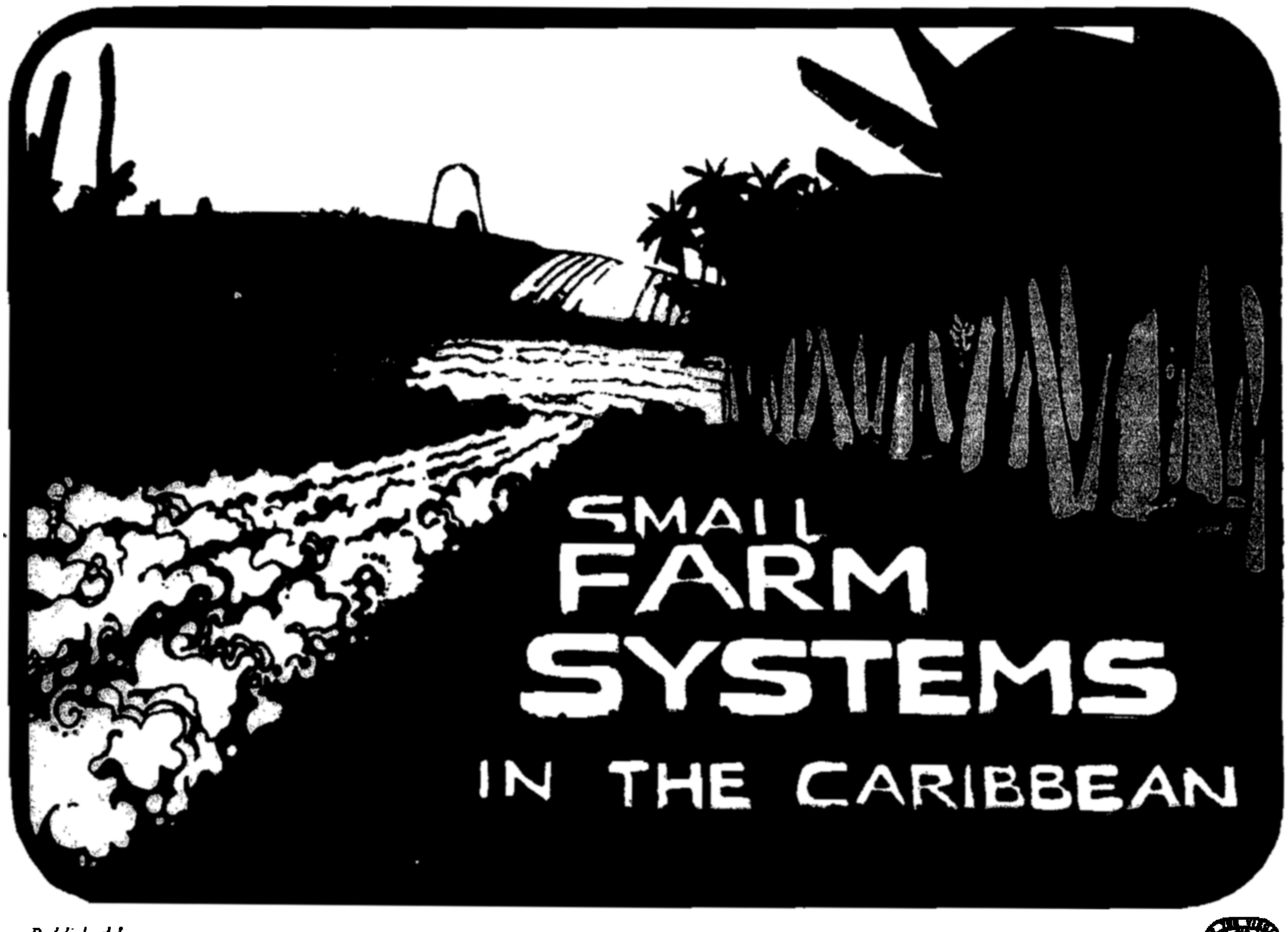

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Breeding Tomatoes for All Seasons

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Tomato genotypes have been field screened for fruit setting ability under high temperature (>30° day >21° night) and humidity conditions. Several genotypes have had good fruit set, but Cl 11d from the AVRDC in Taiwan is the most prominent heat tolerant source in current breeding lines. Fruit characters being selected are: large size, firmness, jointless stems, good shape, good color, even ripening, blossom-end smoothness, and no cracks. Disease resistance being incorporated include Fusarium wilt (*F. oxysporum* f. sp. *lycopersici*) races 1, 2 and 3, gray leaf spot (*Stemphylium solani* Weber), bacterial wilt (*Pseudomonas solanacearum* E. F. Smith), and bacterial spot (*Xanthomonas campestris* pv. *vesicatoria*). To further enhance fruit setting, a parthenocarpy gene (*pat-2*) has been incorporated into heat tolerant genotypes. In 1983, two such lines had yields equal to and greater than Cl 11d under high and low temperature conditions, respectively. This gene combination could result in horticulturally acceptable, multiple disease resistant breeding lines which will set fruit under both high and low temperatures and/or high humidity conditions not conducive to pollination.
Keywords: cold tolerance, disease resistance, fruit set, heat tolerance, *Lycopersicon esculentum* Mill., parthenocarpy, vegetable breeding.

One objective of the tomato breeding program at the University of Florida is to develop varieties or breeding lines which could be either grown as a summer tomato crop in Florida and other tropical areas, or utilized in obtaining varieties with earlier fruit set for fall crop tomatoes in these regions.

It has been well documented by Kuo et al. (1978) and others that high temperatures limit tomato (*Lycopersicon esculentum* Mill.) fruit set, and this reduces production in many tropical and sub-tropical regions of the world. Villareal (1980) points out additional difficulty in attaining fruit set under high rainfall conditions which accompany high temperatures in many tropical areas. Breeding of tomatoes for such adverse conditions has been complicated the lack of high heritability for heat tolerant fruit setting ability (El Ahmadi and Stevens, 1979; Villareal and Lai, 1978). It has been extremely difficult to obtain heat tolerant lines with large fruit size, which probably relates to inefficient pollination. Fruit quality defects such as blotchy ripening and inadequate shelf life have also been problems in tropical regions (Villareal, 1980). Furthermore, fruit cracking increases under high rainfall conditions, especially with greater fruit size.

Tropical tomato production is also limited by diseases. Bacterial wilt (*Pseudomonas solanacearum* E. F. Smith) is probably the most prevalent disease problem in these regions (Yang, 1979). Other destructive diseases in the tropics, depending on location, include: Fusarium wilt (*Fusarium oxysporum* f. sp. *lycopersica*), races 1 and 2 (F_2), gray leafspot (*Stemphylium solani* Weber (S), and bacterial spot (*Xanthomonas cempestris* pv. *vesicatoria*). Recently Fusarium wilt race 3 has been discovered in Florida (Jones et al., 1982), and sources of resistance are being evaluated (Scott et al., 1983). A source of resistance to bacterial spot has been reported recently (Scott and Jones, 1984) which should aid in development of varieties resistant to this pathogen. These resistances need to be incorporated into tomato lines with good heat tolerance, crack resistance, shelf life, ripening, and flavor. This is not an easy task, as evidenced by the general lack of available heat tolerant cultivars to date.

One genetic system which might prove useful in developing improved fruit set under temperature stress is parthenocarpy. Genetic parthenocarpy in tomato is a facultative trait whereby the expression of seedless fruit is greatest under periods of environmental stress such as high temperatures (George et al., 1984; Lin et al., 1983). These fruits have normal locule gel, but no seeds. This trait could be useful in enhancing fruit set, not only under high temperatures, but also under humid, rainy conditions or cool temperatures. Cool temperatures can inhibit fruit set during winter months in Florida, or in higher altitudes of some tropical areas. The sporadic occurrence of cool weather in Bradenton would preclude an effective cold tolerance breeding program.

The purpose of this paper is to report on some breeding approaches being utilized at the University of Florida to develop tomatoes which will set fruit under temperature and humidity stress.

MATERIALS AND METHODS

General Characteristics.

Fruit characteristics being selected for the total breeding program are large size, good shape, smooth blossom ends and shoulders, crack resistance, black shoulder resistance, firmness, good color, even ripening, good flavor, and no defects such as pox, gold fleck, or zippers. Vines are determinate (commonly termed semi-determinate), with adequate vine cover to protect fruit. Standard disease resistances being incorporated into all new varieties are Fusarium wilt races 1 and 2, Verticillium wilt race 1 (*Verticillium albo-atrum* Reinke and Berthold) (Ve) and gray leafspot. Of these, Verticillium wilt is not as important to the heat tolerance program since it is a cool weather disease. New disease resistances being bred are Fusarium wilt race 3, Fusarium crown rot (*F. oxysporum* f. sp. *lycopersici radicus*), bacterial spot, and bacterial wilt. Of these, Fusarium crown rot is probably not important to the heat tolerance program since it is a cool weather disease.

Heat Tolerance

Selection takes place in the field under high temperature (>30° C day, >21° C night) and high humidity conditions prevalent at Bradenton, Florida from mid-May through September. It is rare for night temperature to be less than 21°C during this period and often the temperature drops to only 24°C. Day temperatures rarely exceed 35°C. Afternoon thunderstorms are a common occurrence although they can be sporadic.

Over the years, many accessions from around the world have been evaluated and crosses were made to incorporate heat tolerant fruit setting with more desirable horticultural traits. In 1983, a yield trial was conducted to evaluate some of the more advanced breeding lines. The lines tested were:

1. 7104-1, a small fruited tomato with jointless stem, good fruit color and resistance to S and F_2;
2. 7105-1, a large fruited tomato with jointed stem and resistance to S and F_2;
3. 7106, a large fruited tomato with jointed stem and resistance to S and F_2, and Ve;
4. 7107-SBk, a large fruited tomato with jointed stem, good fruit color with uniform green shoulders and resistance to S and F_2; and
5. 7108-1, a cherry type tomato, with jointless stem, very good fruit color, and resistance to S and F_2.

These lines were compared to Cl 11d, a small fruited heat tolerant accession from the AVRDC in Taiwan which has performed well in the past, and 'Walter', a heat sensitive control. Seed was sown on June 29, and transplanted to the field on August 8, 1983. A completely randomized block design with three block of ten plants per plot was used. Plants were spaced 6 cm apart and staked on raised beds of Eau Gallie sand covered with plastic mulch. Six harvests were made from October 6 to November 9, 1983.

Parthenocarpy

An attempt to combine parthenocarpy with heat tolerant genes was done at Urbana, Illinois. Cl 11d was crossed with 'Severianin,' a Russian variety which has the recessive parthenocarpic gene *pat-2*. Plants were selected for parthenocarpic, heat tolerant fruit set in the F_2 generation, and these selections were further inbred. Five of these inbreds then were grown with the two parent lines under the following three environmental conditions: 1) Bradenton, spring; 2) Urbana, summer; and 3) Bradenton, summer-fall (Scott and George, 1984). Weather conditions are summarized in Table 1. In general environment 1 was cool and wet, followed by moderate conditions; 2 was hot and humid with some moisture stress; and 3 was hot and humid with no moisture stress. Seed for the Brandenton spring experiment was sown on January 4, transplanted to the field on February 18, and four harvests were made weekly from May 10 to May 31, 1983. Seed for the Urbana summer experiment was sown on May 10, transplanted to the field on June 10, and four harvests were made weekly from August 18 to September 8, 1983. Seeding and transplanting dates for the Bradenton summer experiment were as described for the breeding line experiment. Six harvests were made weekly from October 2 to November 9, 1983. All experiments used completely randomized block designs with four blocks of ten plant plots. Spacing between plants was 61 cm at all locations. Plants were staked in Bradenton but not at Urbana.

RESULTS AND DISCUSSION

Of the germplasm evaluated, many genotypes with fruit size >30 g have had good fruit set. One of the most reliable sources of germplasm has been Cl 11d, which is prevalent in many of the pedigrees of present heat tolerant breeding lines. Cl 11d also has tolerance to bacterial wilt although this tolerance does not appear to be acceptable under Florida conditions in the summer months (Sonoda et al., 1978). Progress in development of lines superior to Cl 11d has been made, but the job has been difficult, as is evident by the data from the breeding lines tested in 1983 (Table 2). Earliness of the small fruited lines was equivalent to Cl 11d, and the total yield of 7104-1 was similar to that of Cl 11d (Table 2). The larger fruited lines—7105-1, 7106, and 7107-SBK—tended to be later in fruit set than Cl 11d (Table 2). Early total yields of the experimental lines tended to be greater than that of heat sensitive 'Walter,' but differences were not significant for 7105-1 and 7107-SBK. By the end of the season one larger fruited line, 7105-1, had marketable and total yields equivalent to Cl 11d and better than 'Walter.' All lines had a rather large cull percentage, including 'Walter,' which generally has greater percentages of marketable fruit during cooler weather. Many culls were due to catfacing or cracking disorders, which were prevalent under high temperatures. These results did not inspire a breeding line release at this point, and further testing of other lines is underway in 1984. Several of the newer breeding lines have a reasonably good level of bacterial spot tolerance which is a major problem in Florida during the summer.

Hybrids between heat tolerant inbreds and larger fruited, crack resistant, smooth, heat sensitive, inbreds may be useful to help overcome some of the problems in attaining all these characteristics in heat tolerant inbreds. In work not presented here, it was found that such hybrids had yields comparable to the heat tolerant inbreds, but with greater fruit size (Scott and Jones, 1983).

The use of parthenocarpy offers an alternative approach. Experimental inbreds, 645 and 646, had yields equal or greater than Cl 11d and Severianin under all three environments (Table 3). In the spring, fruit set of the Cl 11d was relatively low when the weather was cool and wet, but the other lines set well primarily because of parthenocarpic expression. Moreover, the percentage of parthenocarpic fruit set during the early spring harvests when the cool and wet weather was prevalent was greater than that shown in Table 3 for the season (Scott and George, 1984). Yields are less for 645 and 646 during the summer seasons, but not significantly different than Cl 11d. Line 645 had greater yield than Severianin at Illinois, due to greater seeded fruit set, presumably due to presence of some heat tolerance genes derived from Cl 11d.

The above data indicate the advantages of combining parthenocarpy with heat tolerant lines. Fruit set can be enhanced during both hot and cool, wet weather. Lines which have better Cl 11d type heat tolerance plus *pat-2* than 645 and 646 could be developed, although efficient selection methodology to obtain both *pat-2* and Cl 11d type heat tolerance needs to be elucidated. Much is still unknown about parthenocarpy in tomatoes. Although *pat-2* is a single gene, the expression of this gene is quite variable. For instance, Severianin was crossed with the heat sensitive cv. Hayslip, F_2's were obtained, and seven selections were made for good parthenocarpic expresison during the spring at Bradenton. When these seven lines were assayed for parthenocarpic set during the summer of 1983, one line set well, two lines segregated a small percentage of good plants, and four lines set poorly. Preliminary data in 1984 indicated the good-setting *pat-2* line had early yields comparable to Cl 11d with greater fruit size, and over 98% of the fruits were parthenocarpic. Thus, it may be easier to use parthenocarpy without Cl 11d type heat tolerance to improve fruit set under environments with temperature and humidity stress. Both approaches in utilizing parthenocarpy are presently being evaluated. All parthenocarpic breeding lines, with and without Cl 11d type heat tolerance, are assayed for fruit set under high temperature and rainfall stress in the summer. Lines which set well parthenocarpically under such conditions will probably also set well under cold stress. Since cold stress occurs only sporadically in central Florida, efficient selection by an alternative method would be difficult.

TABLE 1. Summary of weather data for the three growing seasons used to evaluate heat tolerant and/or parthenocarpic genotypes in 1983.

	Bradenton, Spring				Urbana, Summer			Bradenton, Summer-Fall			
	Feb.	Mar.	Apr.	May	June	July	Aug.	July	Aug.	Sept.	Oct.
Temperature °											
mean high	21.7	22.8	27.2	30.6	28.6	32.1	31.3	33.3	33.3	31.7	30.0
mean low	10.6	11.7	13.9	17.2	17.1	20.4	20.0	22.2	23.3	21.7	18.9
Precipitation (cm)	25.9	21.8	6.1	3.0	23.1[z]	3.6	11.7	19.6	17.8	16.5	12.7

[z] All rain before field transplanting.

TABLE 2. Yield and fruit size for early and total harvests of genotypes tested for heat tolerant fruit setting at Bradenton, Florida, Summer 1983.

	Early Harvest [z]			Total Harvest [y]		
	Yield (kg/plant)		Marketable	Yield (kg/plant)		Marketable
Genotype	Marketable	Total	Fruit Size (g)	Marketable	Total	Fruit Size (g)
Cl 11d	1.41 a [x]	1.93 a	40 b	3.05 ab	4.04 a	34 cd
7104-1	1.21 ab	1.36 ab	48 b	3.43 a	3.93 a	43 c
7108-1	0.92 abc	1.28 ab	43 b	2.07 cd	2.89 ab	28 d
7105-1	0.71 bc	.99 bc	139 a	2.88 abc	3.76 a	122 a
7007-SBK	0.64 c	.94 bc	133 a	2.17 bcd	3.67 a	116 ab
7106	0.64 c	1.15 b	133 a	1.74 d	3.13 ab	128 a
Walter	0.38 c	0.41 c	130 a	1.49 d	2.06 b	105 b

[z] Sum of first 3 harvests, Oct. 6, 14, 20, 1983; crop seeded on June 29, transplanted to field July 11.

[y] Sum of 6 harvests ending Nov. 9, 1983.

[x] Means in column not followed by the same letter are significantly different by Duncan's multiple range test, 5% level.

TABLE 3. Yield and parthenocarpic fruit set for tomato genotypes grown under three environmental conditions in 1983.[z]

	Bradenton, Spring			Urbana, Summer			Bradenton, Summer-Fall		
	Fruit No.	Fruit Wt.	Parthenocarpic	Fruit No.	Fruit Wt.	Parthenocarpic	Fruit No.	Fruit Wt.	Parthenocarpic
Genotype[y]	per plant	(kg/plant)	Fruit Set (%)	per plant	(kg/plant)	Fruit Set	per plant	(kg/plant)	Fruit Set (%)
Severianin	74.4	6.55 a [x]	49.7 a	25.2 b	2.02 b	54.0 a	49.8 b	2.93 b	17.4 a
Cl 11d	70.8	3.50 b	0.0 c	49.9 a	2.35 ab	6.9 c	125.4 a	4.00 a	0.2 b
645	63.9	6.80 a	39.1 b	34.9 b	2.97 a	20.4 b	49.4 b	3.21 ab	14.3 a
646	73.7	6.72 a	46.3 a	30.3 b	2.39 ab	28.0 b	59.1 b	3.30 ab	16.8 a
	NS								

[z] For weather information, see Table 1.

[y] Data shown for the 2 breeding lines which had the most consistent fruit set over all 3 environments. The other 3 breeding lines tested were omitted for simplicity.

[x] Means in column not followed by the same letter are significantly different by Duncan's multiple range test, 5% level. Three other lines not shown were in the statistical analysis. NS = not significant.

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