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Parthenocarpy in the Tomato: Genetics, Physiology and Use

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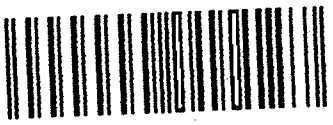

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BARD No. of Proposal I-465-82

Title of Proposed Research

Parthenocarpy in the Tomato: Genetics, Physiology and Use.

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ABSTRACT

Genetics of parthenocarpy in line "RP 75/59" and cultivar "Severianin" was tested under natural low temperature regime under which only seedless fruits were produced.

Results with "RP 75/59" were consistent with the involvement of 3 recessive genes with additive effects for parthenocarpy. Two genes were found to be linked to "diageotropica", dgt, (chromosome 1L site 152) and to "yellow virescent", yv, (chromosome L site 34) respectively.

Results with "Severianin" were consistent with the involvement of 2 recessive genes. One gene, pat-2, has major effects on the expression of parthenocarpy. A second gene, mp-2, influences the expression of pat-2 in both homozygous and heterozygous conformation, and may be present in non parthenocarpic phenotypes. The gene pat-2 was mapped between "solanifolia", sf (chromosome 3 L site III) and "baby lea syndrome", bls, (chromosome 3 L site 74), close to sf.

11 tomato lines considered to carry genes for parthenocarpy were tested in two seasons for allelism to parthenocarpy genes from "Rp 75/59" and "Severianin" using male sterile plants.

The effects of parthenocarpy based on genes in "Rp 75/59" and "Severianin", on fruit quality was evaluated under field and greenhouse conditions.

Comparison of compositional quality of seeded and low seeded fruit from male fertile plants with parthenocarpic fruits from male sterile plants, indicated significant higher solids and higher pH values in the seedless fruit. No differences between fruit types were observed for water insoluble solids: total solids ratio, titratable acidity or color.

Extent of parthenocarpy, plant characteristics and fruit quality traits of 15 tomato varieties, considered sources for genetic parthenocarpy, were evoluated for their potential in breeding programs.

Part A. INHERITANCE STUDIES OF PARTHENOCARPY IN TOMATO

1. Genetics of parthenocarpy in tomato under a low temperature regime

I Line RP 75/59

II Cultivar "Severianin"

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2. Allelic tests for parthenocarpic source material

Lapushner, D., Frankel, R.

Genetics of parthenocarpy in tomato under a low temperature regime:

I. Line RP 75/59

ABSTRACT

Genetics of parthenocarpy in line RP 75/59 was tested under natural low temperature conditions under which only seedless fruits were produced. Results were consistent with the hypothesis that 3 recessive genes with additive effects are responsible for parthenocarpy. Linkage studies, using 40 morphological marker genes located among all tomato chromosome except chromosome seven, revealed linkage of one gene to diageotropica (dgt) located on chromosome 1 L site 152, and a second gene to yellow virescent (yv) located on chromosome 6 L site 34. Location of the third gene involved in parthenocarpy could not be determined. To calculate the power of the linkage tests, a simulation was carried out for 3 genetic models and its results presented by two figures.

INTRODUCTION

RP 75/59 is a strongly facultative parthenocarpic tomato line i.e. seedless fruit will normally be produced if pollination and fertilization of flowers has not been achieved, and seeded fruit will be produced upon pollination and successful fertilisation [1,2,3,4,5]. Consequently, critical test for the inheritance of such parthenocarpy can be made only by consistent repression of pollination or fertilisation by natural or artificial means. Philouze and Maisonneuve used artificial mean (flower emasculation) to repress pollination and fertilisation and concluded that inheritance of parthenocarpy in RP 75/59 is probably controlled by a few recessive genes not allelic to the previously reported recessive genes for parthenocarpy (pat and pat-2) [3,4,6]. Recently Nuez et al[7] proposed a 2 recessive gene model for parthenocarpy in RP 75/59, but insufficient details given on procedure and results of their study make critical interpretation of data given difficult. The present study was undertaken to determine the number and chromosomal location of genes involved in parthenocarpy of line RP 75/59 through linkage to several marker genes under a natural low temperature regime; under such regime all fruits produced were entirely seedless. Thus clear and quantitative classification of parthenocarpy was possible.

MATERIALS AND METHODS

Plant material

Parthenocarpic line (P_2):

RP 75/59 is a F_{13} selection from a cross between the British cv "Atom" and the Russian cv "Bubjekosoko" developed by Reimann-Philipp at the Max Planck Institute for Breeding of Cultivated Plants, Hamburg-Volksdorf, and later taken over by the Federal Research Center for Horticultural Plant Breeding, Ahrensburg, W. Germany[1]. The line is of determinate growth habit, bears globe fruits of 20-30g.

Marker tester stocks (P_1):

Morphological marker stocks used in this study were received from the Tomato Genetics Cooperative Stock Center, Davis, California. Genes in these stocks were homozygous and mainly recessive seedling marker genes; these were located among all tomato chromosomes except chromosome seven. Stocks included:

Accession	Marked chromosomes	Gene symbols
LA 1186	1	au - inv - dgt
LA 1665	1 + 8	dgt; l-al
LA 986	2	s-Wo-aw-d
LA 1444	2 + 5	wv-d; af-tf
LA 1180	3	sy-bls-sf
LA 1430	3	Sy-Ln-bls-sf
LA 917	4	clau-ful-ra-e-di
LA 905	6	yv-m-2-c

LA 1001	9	ha-pum-marm
LA 1003	10	u-lg-h-1-2-t-ag
LA 1113	11	j-hl-a-f
LA 1177	12	alb-mua

Progenies of crosses:

Crosses were made on flowers, emasculated 2-3 days before anthesis, between marker stocks (P_1) and the parthenocarpic line RP 75/59 (P_2) and included: (a) $F_1 = P_1 \times P_2$ (b) $BCP_1 = F_1 \times P_1$ (c) $BCP_2 = F_1 \times P_2$ and (d) $BCF_2 = BCP_2$ selfed

Assessment of parthenocarpy

Parent lines and progenies were examined for parthenocarpy under open field conditions in Yotvata without flower emasculation. Planting date was November 2, 1982. Temperatures prevailing during the flowering season at the plant level are given in figure 1. Under these low temperatures conditions no natural fruit set occurred in non parthenocarpic lines and all fruit produced was entirely seedless. Fruit of the various marker stocks, produced under normal conditions, differ in size. Only non puffy fruits over 1 cm in size, lacking seeds and possessing locular jelly, were considered parthenocarpic. Percentage of parthenocarpic fruit was calculated from the ratio of parthenocarpic fruits to the total number of flowers in the first three inflorescences.

Linkage tests

After assessment of parthenocarpy, plants of the BCP_2 were pruned to induce new growth, flowering, and seeded fruit set in the spring. Seed was

obtained from each plant to produce BCF_2 plants. From each BCP_2 plant 18-24 seeds were sown and the presence of genetic markers determined 1-5 weeks after germination (depending on the markers). Progeny which segregated for a marker was considered to have possessed the marker gene in a heterozygous condition in the BCP_2 generation. Progeny which did not segregate for a marker was considered to have possessed the dominant allele in homozygous condition in the BCP_2 generation. Consequently, when there is no linkage between a marker gene and a gene for parthenocarpy, a 1:1 segregation of homozygous wild type and heterozygous plants for a marker gene in the BCP_2 generation was expected for plants similar to RP 75/59 in parthenocarpy as well as for plants without any fruit set. When there is a linkage, it was expected that BCP_2 plants, which are not parthenocarpic, will mostly be heterozygous for a marker and most of the parthenocarpic plants, which resemble RP 75/59 in level of parthenocarpy will posses the dominant allele for the marker locus in the homozygous condition (see table 4).

Calculation of the power of linkage tests

An investigation with the aim of testing for linkage is usually a lengthy procedure involving the raising of several generations with different marker populations. Therefore, it is important that the design of the experiment should be a reliable one and test for linkage should have a high power (β) i.e. a high probability to end up with a significant result whenever there is considerable linkage or low probability of recombination (r). For the relative simple models, where both the markers and the tested genes are expressed in two (yes/no) categories, we have done simulations to calculate the number (N) of plants needed (generation sizes in the BCP_2 to

achieve certain powers for a one, two, or three gene model). Powers for linkage tests involving quantitative loci were discussed before [13,14]. The power for given N and r is a mixture of binomial probabilities of the rejection area of the test, and the mixing distribution is also binomial, depending on the number of genes, giving the probabilities of homozygotic marker classes of different size. In figure 2 simulation results are presented as a function of r for significance levels $\alpha = 0.05$ and $\alpha = 0.01$, respectively.

RESULTS

As mentioned above all fruit set under the conditions of the Yotvata 82/3 winter season were seedless. In the parthenocarpic line (P_2) RP 75/59 about 75% of all the flowers in the first three inflorescences set seedless fruit; it varied between 55 to 97% among a population of 40 plants. Hence, a minimum of 55% of seedless fruit set among the flowers of the first three inflorescences was considered equivalent in level of parthenocarpy to RP 75/59 (here after called category c). No parthenocarpic fruits - and under the conditions of this test no fruits at all - were found in the non parthenocarpic parent lines (P_1's), in the F_1 populations, and in the BCP_1, populations.

In the BCP_2 populations, of 100-200 plants each, 88.3% of the plants yielded seedless fruits. The differences among the BCP_2 families, progenies of the various P_1 parents, showed no significant different deviations from homogeneity and therefore data were combined (Table 1). The differences among the BCP_2 families, progenies of the various P_1 parents,

showed no significant different deviations from homogeneity and therefore data were combined (table 1).

All plants in the BCP_2 generation were classified into three parthenocarpic categories as to the flowers of the first three inflorescences:

Category a: plants lacking any fruit

" b: plants with a fruit set of less than 55%

" c: plants with a fruiit set of 55% and more

The relative numbers of plants in the parthenocarpic rating a, b and c were tested at the BCP_2 generations using the χ^2 test. Two and four recessive gene models deviated significantly from the results. A three gene model could not be rejected for each of the BCP_2 families. No significant differences between the BCP_2 families were found in a test for homogeneity and data were combined as given in table 2. The resulting χ^2 value from the combined data was 1.16, with P = 0.44 which is in good agreement with the 3 gene model involving 3 recessive genes. A three recessive gene model has been suggested in the past by Philouze and Maisonneuve[6].

If parthenocarpy in the line RP 75/59 is controlled by three independent genes, gene action apears to be controlled in an additive fashion giving a 7:1 segregation of parthenocarpic plants to seeded fruit plants. If the genetic control would not be additive we would expect a 1:7 segregation between parthenocarpic and non parthenocarpic plants (Table 1 and 2).

Linkage studies between parthenocarpy and the marker gene diageotropica, (dgt), located on chromosome 1L site 152, and between parthenocarpy and the

marker gene yellow virescent (yv) located on chromosome 6L site 34 revealed signficant linkages (table 3). The segregation of dgt: dgt^+ and yv. yv^+ in the BCP_2 generation has been found to be random (χ^2 0.02 for dgt and 0.86 for yv with an expected ratio of 1:1). Such random segregation suggests absence of epistasis between parthenocarpy and the marker genes. Thus, the deviation from the expected 1:1 segregation in the BCP_2 appears to be solely the result of linkage between dgt and yv and two of the three independent genes for parthenocarpy acting additively. No linkage has been found between the marker gene invalida (inv), located on chromosome 1L site 140, i.e. 12 units from the location of dgt and a gene for parthenocarpy. Therefore it is likely that the gene of parthenocarpy linked to dgt is located between the site of dgt and the end of the long arm of chromosome 1.

Linkage was not detected between genes controlling parthenocarpy and the following 32 marker genes among the 40 examined:

aurea	(au)	: chr. 1 S site 32
compound cluster	(s)	: chr. 2 L site 30
white virescent	(wv)	: chr. 2 L site 41
Woolly	(Wo)	: chr. 2 L site 46
without authocyanin	(aw)	: chr. 2 L site 59
dwarf	(d)	: chr. 2 L site 70
sunny	(sy)	: chr. 3 S site 46
Lanata	(Ln)	: chr. 3 L site 53
baby-lea syndrome	(bls)	: chr. 3 L site 74
solanifolia	(sf)	: chr. 3 L site 111

clausa	(clau)	: chr. 4 S site 0
fulgens	(ful)	: chr. 4 S site 24
rava	(ra)	: chr. 4 L site 34
entire	(e)	: chr. 4 L site 66
authocyanin free	(af)	: chr. 5 S site 14
trifoliate	(tf)	: chr. 5 S site 40
mottled-2	(m-2)	: chr. 6 L site 77
potato leaf	(c)	: chr. 6 L site 104
lutescent	(l)	: chr. 8 S site 0
anthocyanin loser	(al)	: chr. 8 L site 67
Hoffmanns anthocyaninless	(ah)	: chr. 9 L site 24
pumila	(pum)	: chr. 9 L site 24
marmorata	(marm)	: chr. 9 L site 62
uniform ripening	(u)	: chr.10 S site 14
light green	(lg)	: chr.10 S site 18
hairs absent	(h)	: chr.10 L site 46
lutescent-2	(l-2)	: chr.10 L site 91
tangerine	(t)	: chr.10 L site 95
jointless	(j)	: chr.11 S site 28
hairless	(hl)	: chr.11 S site 48
authocyaninless	(a)	: chr.11 L site 68
fasciated	(f)	: chr.11 L site 95

Absence of linkage with the following six marker genes and genes controlling parthenocarpy could not be fully established due to masking effects of the multiple markers derived from the stocks:

invalida	(inv)	: chr. 1 L site 140
divergens	(di)	: chr. 4 L site 89
wilty	(wt)	: chr. 5 L site 41
authocyanin gainer	(ag)	: chr. 10L site 132
albescent	(alb)	: chr. 12S site 0
multifurcata	(mua)	: chr. 12L site 192

Linkage between the third gene for parthenocarpy and markers used in this study could not be detected; this gene is suspected to be situated on chromosome sectors not tested by markers used in this study, or on chromosome 7 not tested at all.

DISCUSSION

Gene expression of the parthenocarpic line RP 75/59 is facultative, strongly conditioned by the environment [7,8,9] and modified by the genetic background[10,11]. Low temperature regimes have been reported to result into entirely seedless fruits [7,8,9]. High temperature regimes (40°C day 26°C night) also result into parthenocarpic fruit[11,12].

The tomato, being a sequentially flowering plant poses many difficulties in quantification of parthenocarpy. Environmental conditions under natural conditions are unpredictable and may result into both seeded, partially seeded, and parthenocarpic fruit, partial seed count, though often intuitively classified as exhibiting a "parthenocarpic tendency", and possible dependence of normal fruit size on seed count may give rise to ambigous results and misinterpretation of the inherent degree of parthenocarpy. Futhermore, averaging number of parthenocarpic fruits,

inflorescences and flowers which have not been produced at equivalent positions and environments may defeat the purpose of quantifying parthenocarpy.

Means to ensure full parthenocarpy (such as flower emasculation or use of genetic male sterility) may confound results by disturbing balance of growth promoting substances in developing fruit or by pleiotropic effects of male sterility genes.

In the present study the above mentioned difficulties in quantifying parthenocarpy and ambiguities of interpretation of results are minimized. Quantitative classification of parthenocarpy under a low temperature regime is made clear by the sole production of entirely seedless fruits and measurement made at equivalent positions on the plant. Nevertheless, results may be somewhat biased by possible influences of the different genetic backgrounds of the marker tester stocks used to determine the number and chromosomal location of genes involved in parthenocarpy.

BCP_2 populations in this study consisted of 100-200 plants. The simulation made to determine powers of linkage (β) in a 3 gene model for a probability of α = 0.05 (see figure 2) indicated a power of 0.8 for verifying recombination values between r = 0.23 to 0.32.

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Table 1. Plant segregation for RP 75/59 parthenocarpy in parent lines, F_1, BCP_1, and BCP_2 generation (Yotvata, winter 82/83).

Lines	No. of plant		χ^2
	Total	setting seedless fruits	expected ratio 7:1 (3 additive genes model
P_1 = non partheno-carpic lines	150	0	
P_2 = RP 75/59	20	20	
$F_1 = P_1 \times P_2$	150	0	
$BCP_1 = F_1 \times P_1$	473	0	
BC $P_2 = F_1 \times P_2$ families	1416	1250	0.78 not significant at P = 0.05

Table 2. Test of 2, 3, and 4 independent and additive recessive genes models for RP 75/59 parthenocarpy (combined data of all BC P_2 families.

Generation	Total	Number of plants in parthenocarpic categories			χ^2 Expected ratio for		
		a	b	c	2 genes 1:2:1	3 genes 1:6:1	4 genes 1:14:1
BCP_2 families	1416	166	1079	171	388.85**	1.16 NS	156.40*

* significant at P = 0.05

** " " P = 0.01

NS not significant

Table 3. Number of heterozygotic and homozygotic dominant plants for two marker genes in the BCP_2 generation. χ^2 values (as determined by segregation in the BCF_2 generation) for a 1:1 expected ratio.

Marker	Non parthenocarpic plants (a category of parthenocarpy)				Fully parthenocarpic plants (c) category of parthenocarpy				Combined data (a+c category of parthenocarpy			
	group 1 a^+/a^+	group 2 a^+/a	Total	χ^2	group 1 a^+/a	group 2 a^+/a^+	Total	χ^2	group 1 combined	group 2 combined	Total	χ^2
yv	4	16	20	7.2^{**}	1	8	9	5.4^{*}	5	24	29	12.4^{***}
dgt	9	28	31	9.7^{***}	7	25	32	10.1^{***}	16	53	69	19.8^{***}

* significant at P = 0.05

** " " P = 0.01

*** " " P = 0.001

Table 4. Model for genetical composition of phenotypes of P_1, P_2, F_1 and BCP_2 populations with and without linkage of three independent genes for parthenocarpy (p) and a recessive marker gene (a).

	linkage					no linkage				
line	marker and p-gene	non linked p-genes			proportions	marker gene	non linked p-genes			Proportions
P_1	a - p^+/ a - p^+	p^+ /p^+	p^+/p^+		1/1	a /a	p^+/p^+	p^+/p^+	p^+/p^+	1/1
P_2	a^+ - p /a^+ - p	p /p	p /p		1/1	a^+/a^+	p /p	p /p	p /p	1/1
F_1	a - p^+/a^+ - p	p^+ /p	p^+/p		1/1	a /a^+	p^+/p	p^+/p	p^+/p	1/1
BCP_2	a - p^+/a^+ - p	p /p	p /p		1/8	a /a^+	p /p	p /p	p /p	1/16
	a - p^+/a^+ - p	p^+ /p	p /p		2/8	a /a^+	p /p	p /p	p^+/p	3/16
	a - p^+/a^+ - p	p^+ /p	p^+/p	*	1/8	a /a^+	p /p	p^+/p	p^+/p	3/16
	a^+ - p /a^+ - p	p /p	p /p	**	1/8	a /a^+	p^+/p	p^+/p	p^+/p	1/16
	a^+ - p /a^+ - p	p^+ /p	p /p		2/8	a^+/a^+	p /p	p /p	p /p	1/16
	a^+- p /a^+ - p	p^+ /p	p^+/p		1/8	a^+/a^+	p /p	p /p	p^+/p	3/16
						a^+/a^+	p /p	p^+/p	p+/p	3/16
						a^+/a^+	p^+/p	p^+/p	p^+/p	1/16

* plants of category c parthenocarpy heterozygous for the marker genes

** plants of category a parthenocarpy homozygous dominant for the marker gene

plants of category a parthenocarpy segregating 1:1 for the homozygous dominant and the heterozygous marker configuration.

plants of category c parthenocarpy segregating 1:1 for the homozygous dominant and the heterozygous marker configuration.

Figure 1. Temperature means (below) and number of daily hours below 10°C, above 30°C, and between 20-30°C (above) measured at plant height during the field experiment (Yotvata 82/83).

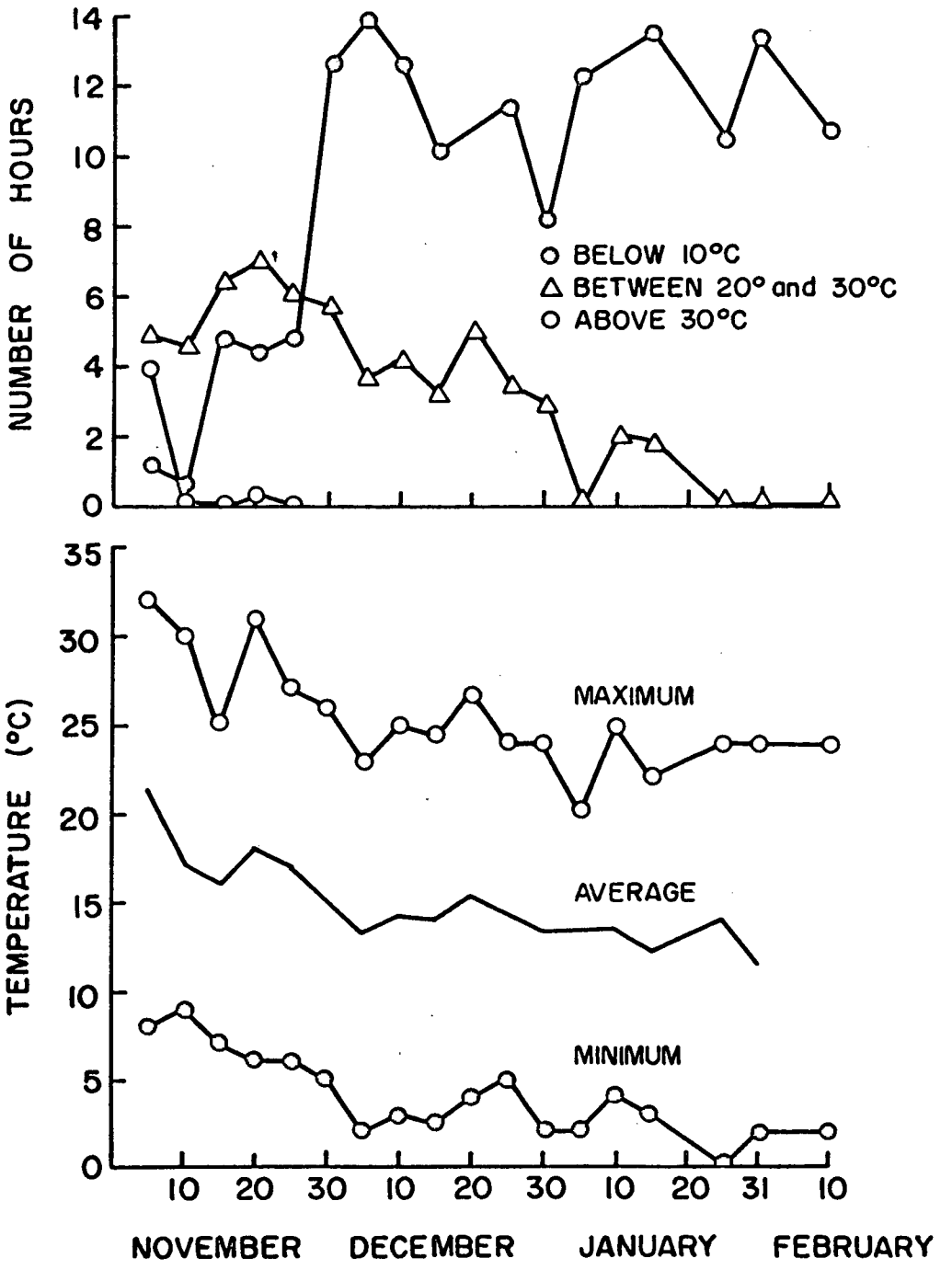
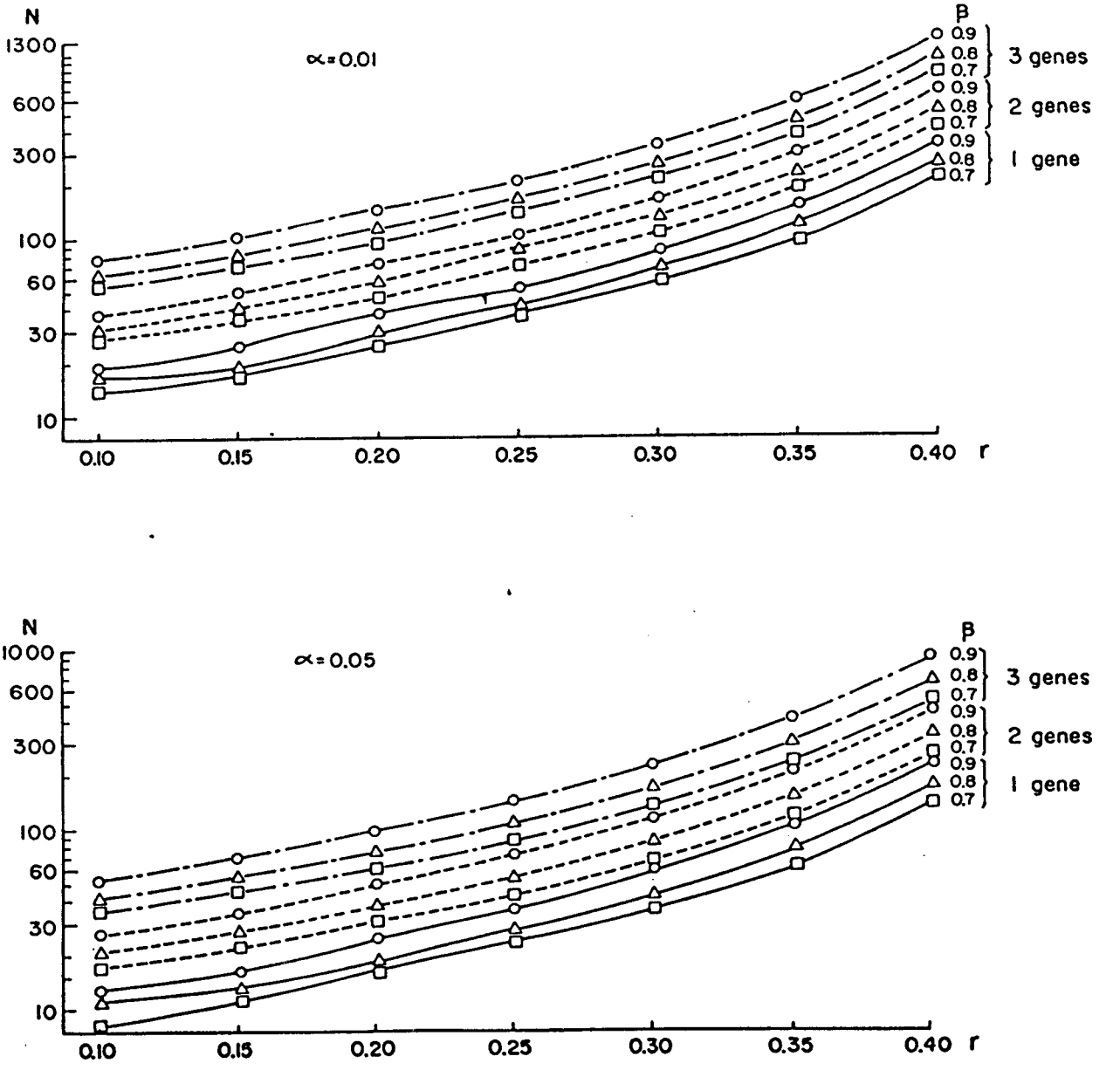


Figure 2. The size of BCP_2 generation needed to achieve a certain power β for given recombination probability under three different models.



Genetics of parthenocarpy in tomato under a low temperature regime: II Cultivar "Severianin."

ABSTRACT

Genetics of parthenocarpy in cv. "Severianin" was tested under natural low temperature conditions under which only seedless fruits were produced. Results were consistent with the hypothesis that 2 recessive genes are involved in the expression of parthenocarpy under low temperature conditions. One gene, pat-2, has major effects on the expression of parthenocarpy. A second gene, mp, in the homozygous form, influences expression of pat-2 in both the homozygous and heterozygous conformation and may be present in non parthenocarpic phenotypes. Linkage tests, using 26 morphological marker genes, located pat-2 between "solanifolia", sf (chromosome 3 site 111) and baby-lea syndrome, bls (chromosome 3 L site 74) close to sf. The location of the minor gene for parthenocarpy, mp, was not detected.

INTRODUCTION

Like the German tomato line Rp 75/59, the U.S.S.R. cultivar (cv) "Severianin" has the ability to naturally set almost normal sized seedless fruits under conditions unfavorable for pollen production and fertilisation, and seeded fruits upon pollination and successful fertilisation of flowers.

Data from crosses between non parthenocarpic cv's and "Severianin" have been interpreted as beeing consistent with a single recessive gene (pat-2) control of the expression of parthenocarpy (Dovedar, 1973; Philouze and Maisonneuve, 1978; Linn 1981). Nuez et al 1986 interpreted results of crosses between parthenocarpic source material and c.v. "Severianin" as beeing consistent with the control of parthenocarpy by non allelic genes:

one in c.v. "Severianin", on in cv. "Subarctic Plenty", and two in line Rp 75/59. However, some inconsistencies with such simple inheritance in "Severianin" exist in the segregation data reported in progenies of crosses of "Severianin" with certain non parthenocarpic lines (Lin et al, 1984; Georgiev et al, 1984) and in crosses betweeen a parthenocarpic line, carrying the pat-2 gene, and certain non parthenocarpic lines (Zoltan-Glick, 1982). Such inconsistencies may have their explaination in difficulties for critically quantifying expression of parthenocarpy and in the presence of some minor genes, in the non parthenocarpic tester lines and "Severianin", effecting extent of expression of parthenocarpy in certain genotypes as pointed out before by Vardy et al (1987).

Attempts to map the pat-2 gene through linkage relations with 18 marker genes have been reported (Philouze, 1983; Lin et al, 1984), but no linkage has been found. The present paper presents results of an effort to determine the number and chromosomal location of genes involved in the expression of parthenocarpy in "Severianin" under a natural low temperature regime in which all fruits produced were entirely seedless.

MATERIALS AND METHODS

Plant material

Parthenocarpic cultivar (P_2):

"Severianin" is a selection from a cross between the cv. Bizon x F_1 (cv "Gruntovij Gribovsky" x Lycopersicum hirsutum) made by N. Solovjeva of the Experimental Station Gribovo near Moscow USSR (see Philouze, 1983). The cultivar is of determinate growth habit and bears deep oblate fruits of 70-130 g.

Marker tester stocks (P_1):

The Tomato Genetics Cooperative Stock Center, Davis, California supplied the morphological marker stocks used in this study, Marker genes in these stocks were all homozygous recessive and were located among all tomato chromosomes except chromosome seven.

Accessions used were:

Accession	Marked chromosomes	Gene symbols
LA 1186	1	au- inv - dgt
LA 1444	2 + 5	wv- d; af - tf
LA 1180	3	sy- bls - sf
LA 917	4	clau -ful- ra - e - di
LA 512	5	mc - tf - wt
LA 905	6	yv - m-2 - c
LA 1179	8	l - bu ; dl - al
LA 1001	9	ah - pum - marm
LA 1166	4 + 10	clau - di; icn - ag
LA 1113	11	j - hl - a - f
LA 1177	12	alb - mua

Progenies of crosses:

Crosses between marker tester stocks (P_1) as females, and cv. "Severianin" (P_2) were made. Progenies grown included F_1, BCP_1, BCP_2 and BCF_2 generations as outlined in Vardi et al (1987).

Assessment of parthenocarpy, linkage tests and calculation of its power was carried out as given in Vardi et al 1987 were the standard to make a critical judgement for the highest level of parthenocarpy was the measure of parthenocarpy in "Severianin."

RESULTS AND DISCUSSION

Under the natural conditions prevailing during the winter season in Yotvata 82/83, used to assess parthenocarpy, all fruit produced were entirely seedless. In the parthenocarpic cv. "Severianin" an average of 71% of all flowers in the first three inflorescences set seedless fruits, ranging between 55-90% among a population of 52 plants. Consequentely, in this study fruit set of 55% and more among the flowers of the first three inflorescences was taken as reflecting the level of expression of

parthenocarpy in the cv. "Severianin" (here after called parthenocarpic level d.).

No fruit set was found in the marker tester stocks (P_1's). However, in 8 out of 11 F_1 families from crosses between the marker tester stocks (P_1's) and "Severianin" (P_2) a low level of seedless fruit set occured (set of 10% - 25%). In these F_1 families no fruit set took place.

The plants of the 8 BCP_2 families (populations of 36 to 82 plants), progenies of the F_1's showing a low level of parthenocarpy, all set parthenocarpic fruits of either high, intermediate or low level. In the 3 BCP_2 families (populations of 36-70 plants), derived from the F_1's in which no fruit set was found, a ratio of 3:1 parthenocarpic to fruitless plants was obtained (Table 1). Such results are not compatible with a single recessive gene control of the expression of parthenocarpy. Our data led us to formulalte a hypothesis of the involvement of one major (pat-2) and one minor gene (mp) in the expression of parthenocarpy in "Severianin". Such model hypothesis enables to assign genotypes to four levels of expression of parthenocarpy as given in Table 2.

In the model given in Table 2 the genotype of "Severianin" is thought to be mp/mp, pat-2/pat-2. P_1's of families 1-8 (listed in table 1) should be of genotypes mp/mp, pat-2^+/pat-2^+, and P_1's of families 9-11 of genotypes mp^+/mp^+, pat-2^+/pat-2^+. We would than expect plants lacking any fruit in all the P_1's and in the F_1's of families 9-11. The F_1's of these families, being of genotypes mp^+/mp, pat-2^+/pat-2, should exhibit absence of parthenocarpy. The BCP_2 families 9-11 should segregate equally into 4 genotypes with 4 levels of parthenocarpy:

mp/mp, pat-2/pat-2 - more than 55% fruit set, level d
mp^+/mp, pat-2/pat-2 - 25-55% fruit set, level c
mp/mp, pat-2^+/pat-2 - up to 25% fruit set, level b
mp^+/mp, pat-2^+/pat-2 - no fruit set, level a

The F_1 families 1-8, being of genotype mp/mp, pat-2^+/pat-2, should according to our hypothesis all be with a low level of parthenocarpy (level

b). BCP_2 families 1-8 should segregate into a 1:1 ratio for genotype mp/mp pat-2/pat-2 with level d. fruit set and mp/mp, pat-2^+/pat-2 with level b fruit set.

Levels a and d of fruit set can unambiguously be considered discrete classes from b + c, d being the level of expression of parthenocarpy in "Severianin", and no seeded fruit occured under the conditions of the present study. But differentiation between level b and c of fruit set is based in our model arbitrarily on the expression of parthenocarpy among the plants in F_1 families 9-11 in which a range of 1-25% of set was observed. Such arbitrary assumption, based on one hypothetical genotype in the F_1, mp^+/mp, pat-2^+/pat-2, does not necessarily reflect expression of a second hypothetical genotype mp/mp, pat-2^+/pat-2 in the BCP_2 generation, which may overlap the level of seedlless fruit set of the genotype in the F_1. Due to the limited number of plants tested in the F_1 and BCP_2, no discrete classes of level b and c could be established and these levels were combined to include 1-54% of fruit set. Table 3 gives a χ^2 test for our hypothesis in which levels b and c have been combined for BCP_2 families 1-8 and BCP_2 families 9-11.

For the expected ratio of 1:1, d:b+c levels, χ^2's for BCP_2 families 1-8 ranged from 0.44 to 3.37 with a χ^2 of 0.0001 and p = 0.999 for all 8 BCP_2 progenies combined. For the expected ratio 1:2:1, d: b+c: a levels, χ^2's for BCP_2 families 9-11 ranged from 1.33 to 2.38, with a χ^2 of 1.86 and P = 0.5-0.25 for all 3 BCP_2 progenies combined (see table 3). These results support our hypothesis for two recessive genes responsible for parthenocarpy in cv. "Severianin" - one major gene (pat-2), and one minor gene (mp) which may be present also in non-parthenocarpic phenotypes (no fruit set in the present study).

Linkage tests between genes for parthenocarpy in "Severianin" and the marker genes sf (solanifolia), located on chromosome 3 L site 111, and bls (baby-lea syndrome), located on chromosome 3 L site 74 revealed significant linkages (table 4). Under the model given in table 2 it is reasonable to assume that these linkages relate to the major gene, pat-2, because only in

linkage with pat-2 (and not with the minor gene mp) the majority of plants with full parthenocarpy in BCP_2 should be homozygous dominant and no segregation of the marker gene occured in the BCF_2 generation.
A 1:1 ratio in BCP_2 for homozygous dominant to heterozygous should be expected for a linkage with mp (as would be for absence of any linkage). The gene pat-2 appears to be located between sf and bls and closer to sf as indicated by the probability values of the χ^2 test (table 4) and absence of linkage with sy (see furtheron).
A power of linkage (B) of 0.8 for pat-2 (see Vardy et al 1987 -one gene model), for the family of the pertinent marker stock consisting of 62 plants, indicates a maximum recombination value, r = 0.31 with = 0.05. A one gene model must be used since no linkage could be detected between the hypothetical minor gene for parthenocarpy mp and linkage markers used in this study.

The minimum recombination values which could be detected in the BCP_2 populations (n = 36-82 plants) were between r = 0.25 to 0.35, for a power of B = 0.8 (Vardi et al 1987). Linkage was not detected between genes controlling parthenocarpy and the following 24 marker genes examined:

aurea	au	: chr. 1 S site	32
invalida	inv	: chr. 1 L "	140
diageotropica	dgt	: chr. 1 L "	152
white virescent	wv	: chr. 2 L "	41
dwarf	d	: chr. 2 L "	70
sunny	sy	: chr. 3 S "	46
clausa	clau	: chr. 4 S "	0
fulgens	ful	: chr. 4 S "	24
rava	ra	: chr. 4 L "	34
entire	e	: chr. 4 L "	66
divergens	di	: chr. 4 L "	89
macrocalyx	mc	: chr. 5 S "	0
anthocyanin free	af	: chr. 5 S "	14
trifoliate	tf	: chr. 5 S "	40
yellow virescent	yv	: chr. 6 L "	34

mottled-2	m-2	: chr.	6	L "	77
potato leaf	c	: chr.	6	L "	104
lutescent	l	: chr.	8	S "	0
bushy	bu	: chr.	8	L "	18
anthocyanin loser	al	: chr.	8	L "	67
jointless	j	: chr.	II	S "	28
hairless	hl	: chr.	II	S "	48
anthocyaninless	a	: chr.	II	L "	68
fasciated	f	: chr.	II	L "	95

Absence of linkage with the following 9 marker genes included in the present study, and genes controlling parthenocarpy could not be established due to masking effects of multiple markers, derived from the stocks, or due to a maximum sensitivity to detect recombination of 25-35 centimorgans (CM).

wilty	wt	: chr.	5	L site	41
dialytic	dl	: chr.	8	L "	29
Hoffmanns anthocyaninless	ah	: chr.	9	L "	24
pumila	pum	: chr.	9	L "	24
marmorata	marm	: chr.	9	L "	62
incana	icn	: chr.	10	S site	37
anthocyanin gainer	ag	: chr.	10	L site	132
albescent	alb	: chr.	12	S site	0
multifurcata	mua	: chr.	12	L site	192

Absence of linkage was reported before between pat-2 and the following genes: y (chr. 1,30), ms-32 (chr. 1,47), aw (chr.2, 59), ms-10 (chr.2,51), ps (chr.2,61), bls (chr. 3,74), Mi (chr. 6,35), c (chr.6,104), sp (chr.6,105), bs-2 (chr.7,34), ls (chr.7,59), bu (chr.8,18), dl (chr.8,29), al (chr. 8,67), Tm-2^2 (chr.9,22), u (chr.10,19). j-2 (chr.11, 0), hl (chr. 11,48), I-2 (chr.11,85), I (chr.11), Ve (chr.12), (see Lin, 1981 and Philouze 1983a,b).

The conflicting results of our linkage test with bls with those of Philouze (1983b) could be due to differences in the genetic background of the marker stocks used, in classification of parthenocarpy, and in differential expression under the environmental conditions of the tests.

CONCLUSIONS

Under the low temperature regime of this study, expression of parthenocarpy in the progenies of crosses between the parthenocarpic cultivar "Severianin" (P_2) and eleven different marker tested stocks (P_1's) was not consistent with a one recessive gene model. The populations of certain F_1's displayed a uniform low level of seedless fruit set and the BCP_2 progeny set seedless fruit with high, intermediate, or low level of expression. In F_1 populations from crosses of "Severianin" with other marker stocks, no seedless fruit set occured, and in the BCP_2 progeny of these crosses a 3:1 ratio parthenocarpic to fruitless plants was obtained. Such data are consistent with the involvement of one major gene (pat-2) and one minor gene (mp) in the genetic control of parthenocarpy in the cv. "Severianin" and presence or absence of the minor gene, mp, in the non parthenocarpic marker tester stocks (P_1's) used in this study. Homozygous mp influences expression of pat-2 in both the homozygous and heterozygous conformation. Linkage tests, between sf (solanifolia), bls (baby lea syndrome), and sy (sunny) and genes for parthenocarpy, located the major gene for parthenocarpy, pat-2, on chromosome 3 between the sites of sf (chr. 3 L, 111) and of bls (chr. 3 L, 74) and closer to sf than bls. The location of the minor gene for parthenocarpy, mp could not be detected by markers used in this study; this gene is suspected to be situated on chromosomes or chromosome sectors not covered by the sensitivity of the present study for detection of linkage, beeing 25-35 CM.

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Table 1. Segregation for parthenocarpy in F_1 and BCP_2 progenies of crosses between marker tester stocks (P_1's) and cv. "Severianin" (P_2)

Families	Number of plants				
		Total parthenocarpic	level of parthenocarpy* >55%	1-54%	0
"Severianin"(P_2)	52	52	52	0	0
1. LA 1186 (P_1)	15	0	0	0	0
P_1 x P_2 (F_1)	15	15	0	15	0
F_1 x P_2 (BCP_2)	36	36	21	15	0
2. LA 1180 (P_1)	15	0	0	0	0
P_1 x P_2 (F_1)	15	15	0	15	0
F_1 x P_2 (BCP_2)	62	62	28	34	0
3. LA 917 (P_1)	15	0	0	0	0
P_1 x P_2 (F_1)	15	15	0	15	0
F_1 x P_2 (BCP_2)	77	76	42	34	1
4. LA 512 (P_1)	15	0	0	0	0
P_1 x P_2 (F_1)	15	15	0	15	0
F_1 x P_2 (BCP_2)	80	80	32	48	0

5. LA 905 (P_1)	15	0	0	0	0
P_1 x P_2 (F_1)	15	15	0	15	0
F_1 x P_2 (BCP_2)	76	76	46	30	0
6. LA 1179 (P_1)	15	0	0	0	0
P_1 x P_2 (F_1)	15	15	0	15	0
F_1 x P_2 (BCP_2)	80	80	32	48	0
7. LA 1166 (P_1)	15	0	0	0	0
P_1 x P_2 (F_1)	15	15	0	15	0
F_1 x P_2 (BCP_2)	80	80	48	32	0
8. LA 1113 (P_1)	15	0	0	0	0
P_1 x P_2 (F_1)	15	15	0	15	0
F_1 x P_2 (BCP_2)	82	82	38	44	0
9. LA 1444 (P_1)	15	0	0	0	0
P_1 x P_2 (F_1)	15	0	0	0	0
F_1 x P_2 (BCP_2)	70	48	14	34	22
10. LA 1001 (P_1)	15	0	0	0	0
P_1 x P_2 (F_1)	15	0	0	0	0
F_1 x P_2 (BCP_2)	36	26	5	21	10
11. LA 4110 (P_1)	15	0	0	0	0
P_1 x P_2 (F_1)	15	0	0	0	0
F_1 x P_2 (BCP_2)	36	30	10	20	6

* % of all flowers in the first 3 inflorescences setting fruits.

Table 2. Model for the genetic control of the expression of parthenocarpy in cv "Severianin" by one major gene (pat-2) and one minor gene (mp)

Level of parthenocarpy	Genotypes
a. plants lacking any fruit	mp /mp , pat-2$^+$ /pat-2$^+$ mp /mp$^+$, pat-2$^+$ /pat-2$^+$ mp /mp$^+$, pat-2 /pat-2$^+$ mp$^+$ /mp$^+$, pat-2 /pat-2$^+$ mp$^+$ /mp$^+$, pat-2$^+$ /pat-2$^+$
b. low level of seedless fruit set (up to 25%)	mp /mp , pat-2 /pat-2$^+$
c. intermediate level of seedless fruit set (25-54%)	mp /mp+ , pat-2 / pat-2 mp$^+$ /mp$^+$, pat-2 /pat-2
d. high level of seedless fruit set (> 55%)	mp /mp , pat-2 /pat-2

Table 3. X^2 test for a two recessive gene model, consistiing of one major (pat-2) and one minor gene (mp), in BCP_2 families in which the F_1 generation were weakly parthenocarpic (families 1-8)* and in BCP_2 families in which the F_1 generation was non parthenocarpic families 9-11)*.

BCP_2 progeny families	parthenocarpy in F_1	parthenocarpy level	BCP_2 No. of plants	X^2	P
1-8	yes	a	1		
		b+c	285		
		d	287	0.0001**	0.999
9-11	no	a	38		
		b+c	75		
		d	29	1.86***	0.5-0.25

* see table 1

** Ho : 1:1 segregation between plants from parthenocarpic level
d: b+c.

*** Ho: 1:2:1 segregation between plants from parthenocarpic level
d: b+c : d.

Table 4. Number of heterozygotic and homozygotic dominant plants for two marker genes in the BCP_2 generation (as determined by segregation in the BCF_2 generation) for 1:1 expected ratio.

Marker	Non parthenocarpic plants (a category of parthenocarpy	Partial parthenocarpy plants b+c category of parthenocarpy				Fully parthenocarpic plants (d category of parthenocarpy)				Combined data			
	Total	group1 a^+/a	group 2 a^+/a^+	Total	χ^2	group1 a^+/a^+	group2 a^+/a	Total	χ^2	Group1 combined	Group2 Combined	Total	χ^2
bls	0	22	12	34	2.94	18	10	28	2.28	40	22	62	5.2*
sf	0	27	7	34	11.76**	23	5	28	11.57**	50	12	62	23.3**

* significant at P =0.05
** " " P = 0.005

ALLELIC TEST FOR PARTHENOCARPIC SOURCE MATERIAL

Efficient utilisation of genetic factors responsible for parthenocarpy in plant breeding requires information on possible allelism of genes present in source material. The two best sources of genes involved in parthenocarpy,
singled out for their utility in plant breeding were of the German line "RP 75/59" and the Russian cultivar (cv) "Severianin" (Philouze, 1985). Parthenocarpy in "RP 75/59" proved to be controlled by genes not allelic to the gene pat-2, the major gene responsible for parthenocarpy in the cv " Severianin" (Philouze and Maisonneuve, 1978; Nuez et al 1986). This study reports tests for allelism between genes for parthenocarpy of "RP 75/59" and "Severianin" and eleven tomato lines considered to carry genes for parthenocarpy which were not derived from "RP 75/59" or "Severianin".

Materials and Methods

To facilitate crossing, the following three male sterile lines, supposedly carrying all genes for parthenocarpy from "RP 75/59" or "Severianin", were used as female parents:

L-147 ms - F_8 selection of breeding line 1613 carrying all genes for parthenocarpy from "RP 75/59".

L-157 ms - F_8 selection of breeding line 1613 carrying all genes for parthenocarpy from "Severianin".

L-165 ms - F_8 selection of breeding line 1630 carrying all genes for parthenocarpy from "Severianin".

The following eleven tomato lines, of Canadian, German or U.S. origin, considered to carry genes for parthenocarpy, were used as pollen parents in the production of F_1 progeny used to test for allelism:

Bubjekosoko

Heinemanns Jubilaum

Priora

Atom

Subarctic Plenty = Beaverlodge (BL) 6081

Oregon 11

Farthest North

Early North

Oregon T5-4

Oregon cherry

Saladette

"RP 75/59" and "Severianin" served as controls for degree of parthenocarpy. F_1 progenies and controls were planted in two seasons. 40 plants of each entry were planted in the first season November 3, 1984. Peak flowering period was in early January, were at least for a few hours night temperatures were below 10°C. 44-99 ripe fruits (0.5-3.5 kg depending on fruit size) were sampled from each hybrid combinations, male parents and controls on April 1985, fruit weight and degree of parthenocarpy determined. 3 categories of fruits were recorded: seedless fruits, fruits with few seeds (1-10 seeds visible in an equatorial cut), and fruits with normal seed count.

In the second season 15 plants were planted November 4, 1986. Ground frost somewhat damaged the plants twice in early and late January. 25-183 ripe fruits (0.9-3.9 kg depending on fruit size) were sampled April 2, 1987 fruit weight and categories of parthenocarpy determined.

Results and Discussion

Red fruit of "Severianin" was 100% seedless in both the 1984/85 and the 1986/87 season. Red fruit of "RP 75/59" in 1984/85 season was 92% seedless and 8% with few seeds and in the 1986/87 season 43% seedless, 7% with few seeds and 50% seedy. Seedless fruit weight of RP 75/59 was 21 g as compared to 44 g of the seeded fruit weight.

Due to the apparent relationship between seed number and fruit weight, the fact that genes with additive effects are involved in the extent of expression of parthenocarpy (as shown in this report) for both "RP 75/59" and "Severianin", as well as the production of both seedless and seeded fruit under the conditions in which these tests for allelism have been carried out, critical and consistent results can not be expected. Scrutiny must be applied to decide on trends in the data of table 1 and 2 giving results of the 1984/85 and 1986/87 season. Furthermore, data for parthenocarpic capacity of the parent lines and the hybrids may be confounded because of differential pollen production, nicking, germination, growth and fertilisation under relative low temperatures.

With all the reservations mentioned, we may still try to integrate expression of parthenocarpy and reduction in weight of parthenocarpic

versus seeded fruit in male parents, hybrids, "RP 75/59", and "Severianin". These are strong indications for allelism between genes in some source material with a least certain genes responsible for parthenocarpy in "RP 75/59" and "Severianin".

"Heinemanns Jubilaum" - allelism with "Severianin".

(itself gave 18% (84/5) to 12% (86/7) of seedless fruit. In crosses with L-165 ms, 85% of fruit was seedless in both season, but fruit weight was much reduced).

"Atom" - allelism with "Severianin"

(itself gave 63% (84/5) to 19% (86/7) of seedless fruit. In crosses with L-165 ms, 57% and 87% of fruit were seedless in 84/5 and 86/7, respectively).

"Subarctic Plenty" - allelism with both "Severianin" and "RP 75/59".

(itself gave 49% (84/5) to 22% (86/7) of seedless fruit. In crosses with L-165 ms, 86% and 95% of fruit were seedless in 84/5 and 86/7, respectively. In crosses with L-147 ms, 83% and 86% of fruit were seedless in 84/5 and 86/7, respectively).

"Oregon 11" - allelism with both "Severianin" and "RP 75/59".

(itself gave 35% (84/5) to 25% (86/7) of seedless fruit. In crosses with L-165 ms, 82% and 94% of fruit were seedless in 84/5 and 86/7, respectively. In crosses with L-147 ms, 75% and 54% of fruit were seedless in 84/5 and 86/7, respectively).

"Oregon T5-4" - allelism with both "Severianin" and "RP 75/59".

(itself gave 35% (84/5) to 93% (86/7) of seedless fruit.

In crosses with L-165 ms, 89% and 96% of fruit were seedless in 84/5 and 86/7, respectively. In crosses with L-147 ms, 79% and 57% of fruit were seedless in 84/5 and 86/7 respectively).

"Oregon cherry" - allelic with "Severianin" and "RP 75/59".

(itself gave 100% (84/5) to 57% (86/7) of seedless fruit. In crosses with L-165 ms, 92% and 100% of fruit were seedless in 84/5 and 86/7 respectively. In crosses with L-147 ms, 82% and 62% of fruit were seedless in 84/5 and 86/7 respectively).

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Table 1

Parthenocarpy and fruit weight in allelic test crosses of source material

Male parent lines		Male sterile female parent: L-147 ms multipat, 1613			L-157 ms pat-2, 1613			L-165 ms pat-2, 1630		
		*no. seeds	**few seeds	*** seedy	no. seeds	few seeds	seedy	no. seeds	few seeds	seedy
Bubjekosoco	% of fruit ****	-	17	84	-	2	98	-	5	95
	av.fr.wgt. *****	-	8	19	-	15	18	-	18	22
Heinemanns Jubilaum	% of fruit	73	27	-	53	28	19	85	11	4
	av.fr.wgt.	17	78	-	22	46	84	25	43	83
Priora	% of fruits	-	17	73	-	7	93	9	9	82
	av.fr.wgt.	-	15	29	-	20	28	24	14	24
Atom	% of fruits	60	26	14	47	38	15	57	27	16
	av.fr.wgt.	14	40	51	15	36	42	21	14	38
Subarctic plenty	% of fruits	83	10	7	91	9	-	86	10	4
	av.fr.wgt.	18	36	50	24	33	-	27	20	63
Oregon 11	% of fruits	75	11	14	92	3	5	82	13	5
	av.fr.wgt.	18	25	40	34	45	50	16	30	55
Farthest North	% of fruits	41	10	49	44	23	33	59	9	32
	av.fr.wgt.	22	15	22	10	15	30	9	34	26
Early North	% of fruits	43	37	20	23	59	18	44	40	16
	av.fr.wgt.	8	28	57	34	42	71	28	32	35
Oregon TS 4	% of fruits	79	13	7	75	14	11	89	11	-
	av.fr.wgt.	10	17	22	17	21	33	16	21	-
Oregon cherry	% of fruits	82	6	12	72	16	12	92	5	3
	av.fr.wgt.	15	17	33	15	18	33	20	30	50
Saladette	% of fruits	60	31	9	26	34	40	69	14	17
	av.fr.wgt	16	54	84	45	50	63	16	46	93

*. seedless fruits
**. fruits with 1-10 seeds
***. fruits with normal seed count
****. % of total fruit number
*****. average fruit weight in g.

TABLE 2. PARTHENOCARPY AND FRUIT WEIGHT IN ALLELIC TEST CROSSES OF SOURCE MATERIAL 1986/87

			Male parent lines selfed			Male sterile female parent lines								
						L-147 ms multipat, 1613			L-157 ms pat-2, 1613			L-165 ms patt-2, 1630		
		cv. name	* no. seeds	**few seeds	*** seedy	no. seeds	few seeds	seedy	no. seeds	few seeds	seedy	no. seeds	few seeds	seedy
Green fruit	% of fruit ****	Bubjekosoco	-	-	100	-	-	100	-	-	100	-	-	100
	av. fr. wgt. *****		-	-	7.8	-	-	16.4	-	-	21	-	-	18.19
Red fruit	% of fruit		-	-	100	2.12	4.25	93.61	1.16	13.95	84.88	1.08	17.39	81.52
	av. fr. wgt.		-	-	12.5	25	15	24.8	15	10	24.3	10	13.1	27
Green fruit	% of fruit	Heinemanns Jubilaum	4.4	7.7	88	2.9	10	87	3.75	5	91.25	6.45	-	93.54
	av. fr. wgt.		25	32.14	45.5	35	31.4	54.5	26.6	40	43.6	45	-	46.38
Red fruit	% of fruit		12	56	32	10	52	38	26.67	33.3	35.5	84.9	15.09	-
	av. fr. wgt.		48.33	65	84.3	68	23.5	69.5	36.6	54	85.62	39.11	55	-
Green fruit	% of fruit	Priora	-	-	100	-	-	100	-	-	100	-	-	100
	av. fr. wgt.		-	-	17.35	-	-	25.8	-	-	26.8	-	-	31
Red fruit	% of fruit		1.36	12.3	86.3	-	3.3	96.7	3.6	30.1	66.3	25	21.4	53.6
	av. fr. wgt.		10	23.8	25.95	-	25	37.2	13.33	20.4	32.7	36.4	30.4	45.3
Green fruit	% of fruit	Atom	-	3.96	96.03	0.8	4.8	94.35	1.5	6.15	92.3	8	6.67	85
	av. fr. wgt.		-	12.5	20.20	15	20	30.4	30	30	26.6	36	25	35.8
Red fruit	% of fruit		18.9	29.3	51.72	19.5	19.5	61.2	26.5	27.9	45.6	87	10.1	2.9
	av. fr. wgt.		21.82	20	24	25	28.3	37	28.3	29.47	45.48	33.3	30	45
Green fruit	% of fruit	Subarctic Plenty (Beaverlodge 6801)	3.4	13.7	83	8.4	11.1	80.5	17	29	54	9	15.5	75.5
	av. fr. wgt.		10	40	17.11	40.15	30	38.1	26	26.5	30	47.5	40	46.4
Red fruit	% of fruit		22	20.5	57.3	86.3	10.3	3.4	77.5	12.5	10	94.8	5.2	-
	av. fr. wgt.		29.3	19.28	23.33	38	36.6	40	44	40	42.5	41.3	53.3	-
Green fruit	% of fruit	Oregon 11	4.6	20.4	75	1.7	1.7	96.5	25	30.4	44.6	-	3.5	96.5
	av. fr. wgt.		10	13.89	18.5	30	30	36.4	22.14	22.4	26.5	-	25	55
Red fruit	% of fruit		25	12.5	62.5	54.4	26.4	19.1	67.8	18.4	13.8	94.3	2.8	2.81
	av. fr. wgt.		37.5	15	27	26.5	27.2	38.5	67.2	40.8	42.2	32.6	25	30
Green fruit	% of fruit	Farthest North	-	-	100	9.1	3.06	87.7	-	2.7	97.3	1.1	3.9	95
	av. fr. wgt.		-	-	4.72	20	13.3	18.4	-	15	19.17	30	23.3	25.6
Red fruit	% of fruit		65.16	1.21	33.71	29.7	5.4	64.8	24	14.1	62	70.5	9.5	20
	av. fr. wgt.		7.5	5	15	25	17.5	23.5	17.28	19.2	24.2	18.05	14.4	23.1
Green fruit	% of fruit	Early North (sp*)	7.9	6.5	85.5	-	13.8	86.2	13.7	13.7	72.6	14.5	8.7	76.8
	av. fr. wgt.		31.6	46	54.1	-	22.2	31.07	14.2	30.7	37	30	28.3	34.3
Red fruit	% of fruit				-	-	66.6	33.3						
	av. fr. wgt.				-	-	24	42						
Green fruit	% of fruit	Oregon T5-4	1.8	0.6	97.6	4.5	1.5	94	1.67	-	98.3	-	2	98
	av. fr. wgt.		5	8	7.52	30	20	26	15	-	32.6	-	40	36.04
Red fruit	% of fruit		93.25	3.85	2.9	57.3	2.7	40	59.4	15.6	25	96.3	-	3.7
	av. fr. wgt.		11.64	10	10	32.1	20	26.7	35.8	32.5	30	42.16	-	40
Green fruit	% of fruit	Oregon cherry	3.4	0.85	95.7	-	-	100	1.67	-	98.3	17.5	-	82.5
	av. fr. wgt.		21.25	30	15.5	-	-	29.9	20	-	32	30	-	33.2
Red fruit	% of fruit		57.3	-	42.6	62.2	16.6	21.1	39.7	20.5	39.7	100	-	-
	av. fr. wgt.		11.15	-	16.7	23.8	20.7	30.0	27.7	23.7	32.2	36.7	-	-
Green fruit	% of fruit	Saladette	4.7	12.6	82.7	-	8	92	6	14	80	1.4	1.4	97
	av. fr. wgt.		15	27.2	37.5	-	35	44.3	33.3	44.2	41.5	50	30	60.6
Red fruit	% of fruit					80.8	19.2	-	79.6	15.6	4.7	56.7	40	3.3
	av. fr. wgt.					41.4	38	-	23	37	46.6	68	68.3	110

* seedless fruits
** fruits with 1-10 seeds
*** fruits with normal seed count
**** % of total fruit number
***** average fruit weight in g.

Part B. EFFECTS OF PARTHENOCARPY ON FRUIT QUALITY OF TOMATO

1. Comparison of fruit quality among two parthenocarpic tomato lines segregating for male sterility

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2. Evaluation of 15 tomato varieties as to the expression of parthenocarpy and fruit quality under extreme temperatures in the greenhouse and the field

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B-1.

Comparison of fruit quality among two parthenocarpic tomato lines segregating for male sterility.

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Effects of Parthenocarpy on Fruit Quality in Tomato[1]

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ABSTRACT. Two parthenocarpic tomato (Lycopersicon esculentum Mill.) lines (L-147C and L-157D) segregating for male sterility were grown in the field at Davis, CA in 3 plantings during the summer of 1985. Male-fertile plants produced both seeded (showing more than 5 seeds when cut in half transversely) and low-seeded (showing 5 or fewer seeds when cut) fruits, whereas male-sterile plants produced only parthenocarpic fruits. The objective of the experiment was to compare the compositional quality of seeded and low-seeded fruits from male-fertile plants with parthenocarpic fruits from male-sterile plants. Fruits were thinned from male-fertile plants so that they would have fruit loads similar to the male-sterile plants. Parthenocarpic fruits were found to have higher percent soluble solids than low-seeded fruits which in turn had higher values than seeded fruits. In general, parthenocarpic and low-seeded fruits had higher pH values than seeded fruits. Only seeded and parthenocarpic fruits were used to compare total solids, the ratio of water insoluble solids/total solids (WIS/TS) titratable acidity and color. Parthenocarpic fruits, in general, had significantly higher total solids than seeded fruits. No consistent differences between fruit types were observed for WIS/TS ratio, titratable acidity or color.

Increased soluble solids in processing tomatoes (Lycopersicon esculentum Mill.) results in lower processing costs, greater case-yield of paste products and improved flavor. Consequently, one of the major objectives of tomato breeders is to raise the soluble solids content without reducing yield. Rick (1974) demonstrated that wild species may be useful sources of high solids in breeding programs. However, more recently, progress using this approach has been limited (Stevens and Rudich, 1978) and other genetic approaches may be required to make further gains.

Much evidence indicates that both genetically and artificially induced parthenocarpic fruits have higher soluble solids than seeded fruits. Falavigna et al. (1978) reported that parthenocarpic segregates from crosses between seeded cultivars and sha-pat lines had, on the average, 1°Brix higher soluble solids than seeded segregates. In a comparison of seeded and seedless fruits of 2 lines (68-116 and 68-117), Richter (1972) found that seedless fruits had greater percent sugar content than seedless fruits. Dryanovska (1975) reported that seedless fruits of the cvs. Eva and Pioner, induced by pollination with gamma ray-irradiated pollen, had both higher percent sugar and percent soluble solids than seeded fruits produced by pollination with nonirradiated pollen. Likewise, Janes (1974) found IBA-induced parthenocarpic fruits to have higher percent sugar and soluble solids than nontreated fruits. However, using the cvs. Severianin, PSET-1 and 75/59, Gull et al. (1984) reported no difference in soluble solids between seeded and seedless fruits. Also, Dryanovska (1975) reported little, if any, advantage in soluble solids of seedless fruits compared to seeded fruits in the cv. Deva. Thus, further work is required to determine the potential of parthenocarpy as a means of increasing the soluble solids content of tomato cultivars.

Because of the excellent expression of parthenocarpy in 'Severianin' and 75/59; it was decided to use lines derived from these 2 sources in this study. Parthenocarpy in 'Severianin' has been reported to be controlled by a single recessive gene pat-2 (Philouze and Maisonneuve, 1978b), whereas control in 75/59 is thought to be conferred by at least 3 genes, none of which are allelic with pat or pat-2 (Philouze, 1983; Philouze and Maisonneuve 1978a). The goal of this study was to examine the effect on quality, primarily total soluble solids, of parthenocarpy as controlled by pat-2 and the polygene source from 75/59. In addition, comparisons of total solids, water insoluble solids/total solids ratio, pH, titratable acidity and color were made.

MATERIALS AND METHODS

Plant material. Two BC_xF_9 parthenocarpic lines (L-147C and L-157D) segregating for male sterility (ms-47, see Zischke, 1986) or (spontaneous recessive mutation in breeding material of D.L.) were used in this study. These lines originated from single heterozygous fertile plants selected from BC_xF_8 breeding lines which were developed at the Volcani Center, Israel by D.L., and originated from the crosses 1613 x 75/59 and 1613 x 'Severianin', respectively. The fertile and sterile segregates were considered to be near isogenic lines. The 75/59 line was developed at the Max Planck Institute, Ahrensburg, Germany by Reimann-Philipp and 'Severianin' was released by the Experimental Station of Gribovo in the U.S.S.R. Seeds of this cultivar were provided by J. Philouze, INRA, Montfavet, France. The expression of parthenocarpy in each of these lines is facultative; seeded fruits are produced under conditions suitable for pollination and fertilization whereas parthenocarpic fruits are produced under suboptimal conditions. The 1613 is a male-sterile breeding line developed at the ARO.

Experimental methods. Seeds of L-147C and L-157D were sown in 0.7 L pots containing sterilized potting soil and grown to the cotyledon stage; the seedlings were then transplanted into speedling trays. Seeds were sown on three dates and transplanted to the field approximately 5 weeks later on 14 May, 12 June and 20 June, 1985. Each planting was arranged in a completely randomized block design with 4 replicate blocks. Within each block two adjacent beds were assigned to each cultivar; each bed measured 15 x 1.5 m and contained 25 plants spaced at 60 cm intervals in a single row. After transplanting, the experiment was cared for according to normal cultural practices used for processing tomatoes in California. At flowering, male-sterile (MS) plants were identified. In order to compare the quality of seeded and seedless fruits, one male-fertile plant was paired with each MS plant. Fertile plants were selected to resemble their corresponding MS plant in size, fruit load and developmental stage as much as possible. Based on our previous observation that male-fertile plants produced more fruit than male-sterile plants, each male-fertile plant was thinned of fruit in order to have a fruit load similar to its corresponding MS plant. The unthinned male-sterile (UMF) plants were used as references for normal fruit production.

Yield and quality measurements. Fruits were harvested from each plant on two occasions. The first harvest included only red fruit while the second harvest included all remaining fruits (green, ripening and red). The second harvest was performed approximately two weeks following the first harvest in each planting. At the first harvest, fruits from each plant were weighed, counted and cut in half transversely. Fruits from thinned male-fertile (TMF)

plants were divided into 2 groups; one group consisted of fruits showing 5 or fewer seeds while the second group was comprised of fruits showing more than 5 seeds. Fruits from the first group were termed "low-seeded" while the second group was termed "seeded". All fruits from MS plants showed no seeds. Fruits from the second harvest were weighed and added to weights from the first harvest to determine total yield.

Only fruits from the first harvest were used for determination of quality components. Fruits were blended for one minute using a Waring Blendor and the puree was poured through a pulper to remove seeds and skins. Total soluble solids (TSS) as °Brix were measured with a Bellingham and Stanley Model RFM 80 refractometer using filtered serum. Titratable acidity was measured by titrating 10 ml of puree mixed with 50 ml of H_2O to pH 8.1 with 0.1 N NaOH; pH was determined with a Beckman pH meter. The percent total solids (TS) was measured using a CEM Moisture/Solids Analyzer and percentages of TSS and TS were used to calculate the ratio of water insoluble solids to total solids (WIS/TS) according to the formula:

$$\frac{WIS}{TS} = \frac{\frac{\%TS - \%SS}{100 - \%SS}}{\%TS} \times 100.$$

Color of de-aerated puree was measured using an Agtron M500A and calculated as green/red x 48.

TSS and pH were measured on all plants examined, 133 and 126 for L-147C and L-157D, respectively. However, due to time limitations, it was possible to measure TS, TA and color on only 48 and 35 plants of the former and latter, respectively. These plants were evenly distributed throughout all 3 plantings. A limited amount of sample made it possible to analyze low-seeded fruits from TMF plants for TSS and pH only.

Statistical analyses. For TSS and pH, observations of TMF and MS plants were treated as pairs in a repeated measures analysis of variance. Differences between plant type means were tested for significance using Tukey's test. For all other comparisons, paired t-tests were used to compare observations of TMF and MS plants and unpaired 2-tailed t-tests were used to compare observations of UMF plants with TMF or MS plants.

RESULTS

The percentages of seeded fruits produced by TMF plants of L-147C and L-157D are presented in Table 1. In both lines the percentage of seeded fruits increased in later plantings and in each planting L-147C had a higher percentage of seeded fruits than did L-157D.

As expected, in all 3 plantings UMF plants of both lines had significantly greater yield than did either TMF or MS plants (Table 2). In most cases TMF plants tended to have higher mean yields than did MS plants, but only in planting 1 of L-147C was this difference significant. While there were significant differences in fruit size between seeded and parthenocarpic fruits, neither fruit type was consistently larger. As might be expected, fruits from UMF plants were smaller than fruits from TMF or MS plants in most cases. Low seeded fruits from TMF plants were in all cases significantly smaller than seeded fruits (Table 2).

Fruits from MS plants consistently had higher percent TSS than low-seeded fruits from TMF plants which, in turn, generally had significantly higher TSS than seeded fruits (Table 3). With 1 exception, parthenocarpic fruits also had significantly higher percent TS than seeded fruits from TMF plants. Parthenocarpy had little effect on partitioning of fruit dry matter between

water soluble and water-insoluble fractions as the WIS/TS ratios of seeded and seedless fruits were similar with 1 exception.

Seeded fruits generally had lower mean pH values than did either MS parthenocarpic fruits or TMF low-seeded fruits, although the differences were not always significant (Table 4). There was little difference in pH between the latter 2 types. TA values did not reflect this trend in pH. In the first planting, fruits of MS plants had significantly greater TA than TMF fruits, however no significant differences were observed in later plantings. No consistent effect of parthenocarpy on fruit color was detected.

DISCUSSION

A problem in assessing the quality characteristics of parthenocarpic fruits is designing a system for comparing seeded and seedless fruits. Previous studies have used artifically induced parthenocarpic fruits (Janes, 1941; Dryanovska, 1975), seeded and parthenocarpic fruits from the same plants (Richter, 1972; Gull et al., 1984) and F_2 populations segregating for parthenocarpy (Falavigna et al., 1978). Philouze (1985) has used emasculation and artificial pollination to study the expression of parthenocarpy in different cultivars as well as near-isogenic lines to study the effect of parthenocarpy on horticultural characteristics (Philouze, 1984). While each of these systems has particular advantages, it was decided to employ parthenocarpic lines segregating for male sterility in this study since they allowed the use of large numbers of plants while assuring the production of seedless fruits. In addition, this system avoided any adverse effects which emasculation might have on transport of assimilates to developing fruits.

Because of large variability for seed number, fruits from male-fertile plants were divided into 2 categories, low-seeded and seeded. Time limitations did not permit counting the number of seeds in each fruit, and therefore fruits were categorized based on the number of seeds visible in transverse cross-sections. Similarly, Lin et al. (1984) classified fruits as being parthenocarpic if fewer than 5 seeds could be seen in a cross section.

Preliminary experiments showed that the male-fertile plants set significantly more fruits than the MS plants. Since the percentage of TSS has been shown to be affected by yield (Stevens and Rudich, 1978), fruits were removed from male-fertile plants so that they had fruit loads comparable to the male-sterile plants. Significantly higher percent TSS values were found for parthenocarpic fruits from MS plants than seeded fruits from TMF plants in both lines in all three plantings. In a further analysis of the data, only pairs of plants in which the MS plant had greater yield than the TMF plant were considered. In this comparison, parthenocarpic fruits still had significantly greater percent TSS than seeded fruits. Averaged over all three harvests, MS plants of L-157D had a mean yield and percent TSS of 3.3 kg per plant and 6.5% while TMF plants had mean values of 2.3 kg per plant and 5.6% TSS for seeded fruits. Comparable values for L-147C were 3.1 kg per plant and 6.7% for parthenocarpic fruits and 2.4 kg per plant and 5.8% for seeded fruits.

These results are not consistent with the findings of Gull et al. (1984) who reported no difference in soluble solids between seeded and parthenocarpic fruits of 'Severianin', 75/59 and a pat-2 line 'PSET-1'. Possible reasons for this difference in results include different genetic backgrounds and/or growing conditions. Also, Gull et al. harvested parthenocarpic and seeded fruits from the same plants, whereas in this study

seeded fruits were harvested from male-fertile plants and parthenocarpic fruits from MS plants. A possible criticism of using male sterility to assure the production of seedless fruits is the difficulty of separating the effects of parthenocarpy from the effect of male sterility or closely linked genes. However, the observation that low-seeded fruits from TMF plants had higher TSS and TS than seeded fruits indicates that at least some of the difference in solids between seeded and parthenocarpic fruits is related to seed number. This conclusion is supported by work of Janes (1941), Richter (1972), Dryanovska (1975) and Falavigna et al. (1978).

The effect of parthenocarpy on pH and acid content of fruits is not clear. In this study, higher pH values were generally associated with parthenocarpy, although seedless fruits had equal or greater TA values than seeded fruits. Similarly, Janes (1941) reported parthenocarpic fruits to have higher pH, but unlike our results found seeded fruits to have greater TA. Both Richter (1972) and Dryanovska (1975) reported only acid content. Richter found parthenocarpic fruits to have greater acid content than seeded fruits whereas Dryanovska reported the opposite. Thus, the effect of parthenocarpy on the relative acid contents and pH values of seeded and seedless fruits may depend on the method of achieving parthenocarpy, genotype and/or cultural conditions. Considering the pH data, the observation that seedless fruits had similar or higher TA values was suprising. However, several previous reports (Anderson, 1957; Lower and Thompson, 1967) have also indicated poor correlation between pH and titratable acidity, possibly due to variable citrate/malate ratios and/or phosphorus concentration (Stevens, 1972). Despite the higher pH of seedless fruits, none of the values were unacceptable for commercial purposes.

Genetic background and environmental factors may also affect the relative

sizes of parthenocarpic and seeded fruits (Philouze and Maisonneuve, 1978c). In the first and second plantings of this study seeded and parthenocarpic fruits of L-147C were of similar sizes, but parthenocarpic fruits of L-157D were significantly larger than their corresponding seeded fruits. In planting 3, seeded fruits were significantly larger than seedless fruits in both lines.

The source of parthenocarpy affected fruit size, the percentage of seeded fruits and in some cases fruit quality. Fruits derived from 'Severianin' (L-157D) tended to be larger and exhibited a lower percentage of seeded fruits than fruits derived from 75/59 (L-147C) (Tables 1 and 2). L-147C fruits tended to have higher TSS, TS and pH than L-157D. No consistent differences between sources of parthenocarpy could be detected for WIS/TS, TA or color.

While the conclusions which can be drawn are limited to the genotypes and environmental conditions of this experiment, the data do suggest that it may be possible to improve the soluble solids content of tomatoes by introducing genes controlling parthenocarpy. Unpublished observations suggest that in addition to high pH and small fruit size, potential problems include soft fruits and low yield. Because the expression of parthenocarpy in the genotypes used in the study is facultative, this material might be used in locations where temperatures are either too high or too low for normal fruit and seed set. Use under conditions favorable for seed set would require very intense expression of parthenocarpy. Seeds of these parthenocarpic lines would have to be produced under optimal temperature conditions and low seed yields would most likely have to be compensated for by growing extra plants, however it is not clear at this time whether seed yields would be sufficient to be economical.

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Table 1

Percentage of seeded fruits (fresh weight basis) from thinned male-fertile plants.[z]

Line	Planting 1	2	3
L-147C	54.5a[y]	71.8a	80.3a
L157D	36.2b	60.3b	71.9b

[z] Fruits used were from first harvest.

[y] Values in a column followed by the same letter are not significantly different at the 0.05 level.

Table 2

Yield (kg/plant) and fruit size (g/fruit) of L-147C and L-157D tomato lines

Character	Plant Type[z]	Tomato Line L-147C Planting 1	L-147C Planting 2	L-147C Planting 3	L-157D Planting 1	L-157D Planting 2	L-157D Planting 3
Yield	UMF	4.2a[y]	3.5a	3.8a	4.3a	3.6a	4.2a
	TMF[x]	3.7b	2.5b	2.5b	3.3b	2.7b	2.3b
	MS	2.9c	2.5b	2.3b	3.2b	2.6b	2.0b
Fruit Size	UMF	47.4a	50.3bc	40.1c	54.3b	52.9c	48.7c
	TMF (s)[w]	42.2a	53.6ab	64.2a	57.2b	62.0b	76.1a
	TMF (ls)	32.7b	48.8c	48.0b	43.5c	52.7c	61.0b
	MS	48.3a	55.0a	54.3b	67.5a	68.0a	57.8b

[z] UMF, unthinned male-fertile plant; TMF, thinned male-fertile plant; MS, male sterile plant.

[y] Values in a column followed by the same letter are not significantly different at the 0.05 level.

[x] Yields include both low-seeded and seeded fruits.

[w] s, seeded fruits, ls, low-seeded fruits.

Table 3

Total soluble solids (TSS), total solids (TS) and water insoluble solids/total solids ratio (WIS/TS) of L-147C and L157D tomato lines.

Character	Plant Type[z]	Tomato Line L-147C Planting 1	L-147C Planting 2	L-147C Planting 3	L-157D Planting 1	L-157D Planting 2	L-157D Planting 3
Total Soluble Solids (%) (TSS)	TMF (s)[y]	5.67c[x]	5.83c	5.41c	5.48c	5.76b	5.37b
	TMF (ls)	5.96b	6.19b	5.92b	5.82b	5.87b	5.65b
	MS	6.96a	6.82a	6.86a	6.26a	6.54a	6.56a
Total Solids (%) (TS)	TMF	6.26b	6.37b	6.15b	6.48a	6.49b	6.07b
	MS	7.55a	7.51a	7.35a	7.02a	7.19a	7.19a
WIS/TS	TMF	0.112a	0.101a	0.093a	0.144a	0.115a	0.111a
	MS	0.105a	0.114a	0.098a	0.111b	0.111a	0.104a

[z] UMF, unthinned male-fertile plant; TMF, thinned male-fertile plant; MS, male sterile plant.

[y] s, seeded fruits; ls, low-seeded fruits.

[x] Values in a column followed by the same letter are not significantly different at the 0.05 level.

Table 4

PH, titratable acidity and color of L-147C and L-157D tomato lines.

Character	Plant Type[z]	Tomato Line L-147C Planting 1	L-147C Planting 2	L-147C Planting 3	L-157D Planting 1	L-157D Planting 2	L-157D Planting 3
pH	TMF (s)[y]	4.23b[x]	4.14c	4.20c	4.15a	4.09b	4.15c
	TMF (ls)	4.27a	4.22b	4.34a	4.18a	4.17a	4.29c
	MS	4.27a	4.27a	4.25b	4.15a	4.18a	4.21b
Titratable Acidity (% citric acid)	TMF	0.48b	0.48a	0.51a	0.53b	0.53a	0.48a
	MS	0.57a	0.49a	0.54a	0.61a	0.51a	0.51a
Color	TMF	31.1a	26.8b	33.9a	35.0a	33.4a	32.4a
	MS	34.3a	31.3a	35.6a	31.6a	29.8b	34.4a

[z] UMF, unthinned male-fertile plant; TMF, thinned male-fertile plant; MS, male sterile plant.

[y] s, seeded fruits; ls, low-seeded fruits.

[x] Values in a column followed by the same letter are not significantly different at the 0.05 level.

Evaluation of 15 tomato varieties as to the expression of parthenocarpy and fruit quality under extreme temperatures in the greenhouse and the field.

Abstract

Fifteen tomato varieties were evaluated under field and greenhouse conditions to determine which varieties have the best potential as parents in a breeding program for parthenocarpy. The percentage of soluble solids (SS) and pH of seeded and seedless fruits from these varieties were compared to investigate whether parthenocarpy was related to superior fruit quality.

It is concluded that 'Severianin' has the attributes to be good parental material for a breeding program for parthenocarpy since it showed good yield potential, acceptable fruit size of seeded and parthenocarpic fruits and moderate expression of parthenocarpy. It was one of the late varieties, however. The varieties '75/59. 'Oregon T5-4' and 'BL 6807' had the highest degree of parthenocarpy and can also be considered as good parental material for parthenocarpy; however, these varieties may require more breeding work because of their poor yields and small fruits. There were no consistent differences between seeded and seedless fruits for SS or pH.

During 1984, two experiments were conducted at Davis with the goal of evaluating 15 varieties for their ability to set parthenocarpic fruit under extreme temperatures and to determine whether seeded and parthenocarpic fruit set on the same plant differed in percent soluble solids and/or pH. In experiment 1, the varieties were transplanted to the field in early spring so that fruit set would occur under both low and moderate temperatures. It was expected that these conditions would result in parthenocarpic and seeded-fruit development on the same plant. Experiment 2 was similar except that the varieties were grown in a greenhouse, initially under temperatures favoring seeded fruit formation and later under high temperatures favoring parthenocarpic.

The following sections describe the methods used and discuss the results obtained in these experiments. These sections are taken from a thesis prepared by Andres Casas Diaz, who worked on this project as part of his M.S. project in the Department of Vegetable Crops, UC Davis.

MATERIALS AND METHODS

PLANT MATERIAL: Fifteen tomato varieties were evaluated in each experiment (field and greenhouse). They were: 'Bubjekosoco', 'Heinemanns Jubilaum', 'Priora', 'Atom', 'Atom x Bubjekosco' F12 (AxB), '(Atom x Bubjekosoco) x (Priora x Heinemanns Jubilaum)' F10 ((AxB) x (PxHJ)), 'BL 6807', 'Oregon 11', 'Farthest North', '557', 'Oregon T5-4',

'Oregon Cherry', 'Severianin' and 'Saladette'. Seeds were obtained from Dr. Rafael Frankel of the Volcani Institute, Bet Dagan, Israel.

EXPERIMENTAL PROCEDURES (FIELD EXPERIMENT): Seeds of the fifteen varieties were sown in 0.7 l pots containing sterilized soil. After one week, the seedlings were transplanted into speedling trays. Seedlings were transplanted to the field on 23 March, 1984. Each variety was placed in plots 3.60 m long and 1.50 m wide. Each plot contained six plants and each variety had five replications which were completely randomized throughout the experimental area.

Varieties were evaluated for the following characteristics: 1) presence or absence of green shoulder, 2) fruit shape, 3) concentration of fruit set, 4) growth habit, 5) vine size ,67) leaf cover and 7) upright or postrate plant.

The rate of plant development was noted in three ways: 1) number of days from transplanting to initiation of flowering; 2) developmental stage of first and third flower clusters 24 and 38 days after transplanting, respectively; 3) number of days from transplanting to breaker stage (at least one fruit).

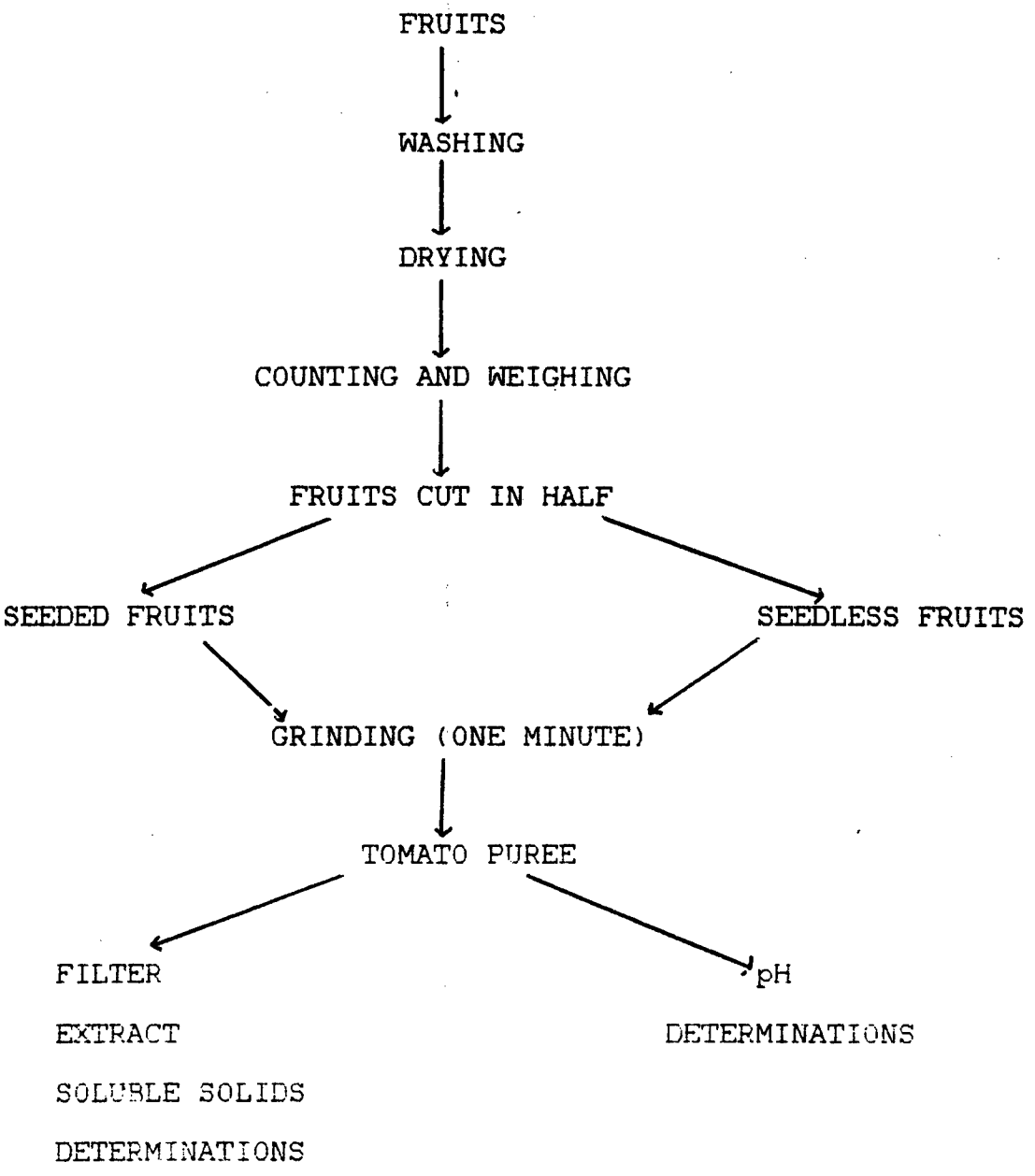
Four plants were selected from each plot for harvesting of fruits. These plants were harvested twice. The first harvest occurred between 14 June and 2 July and included only red fruits. The second harvest included all fruits (green, ripening and red) and was done between 5-18 July. At each harvest, fruits harvested from each plant were weighed, counted and cut in half transversely. Those fruits which showed more than five seeds were considered as seeded fruits, those with five or less seeds were classified as parthenocarpic fruits. Green fruits were not included in this determination of parthenocarpy. Percentage of parthenocarpy was based on fruit number.

The percentage of soluble solids and pH were determined at the Fruit Quality Laboratory, Department of Vegetable Crops, UCD. The steps followed in sample preparation and measurement are outlined in Figure 1 and additional information can be found in Appendix 3. Only red fruits were used in quality measurements.

Fruit size, pH and SS measurements of seeded and seedless fruits were compared using paired t-tests.

EXPERIMENTAL PROCEDURES (GREENHOUSE EXPERIMENT): The fifteen tomato varieties were sown and handled as described

Figure 1. Sample preparation for Field and Greenhouse Experiments



for the Field Experiment. The seedlings were transplanted into beds in a greenhouse on 1 May, 1984. Each plot, measuring 3.60 m x 0.60 m, contained six plants, evenly spaced. Plots were replicated four times and were completely randomized throughout the greenhouse. To measure the influence of high temperature on the expression of parthenocarpy in the different varieties, the temperature was shifted from 25o/18oC to 40o/26oC on 24 June. Clusters which set fruit prior to the shift were labeled and the remaining flowers on those clusters, if any, were removed. Flowers were vibrated daily. For harvest, four plants from each plot were selected. Plants were harvested twice; the first harvest from 20 July to 30 July included only fruits set under cool temperatures. Meanwhile, the second harvest, from 31 July to 13 August, consisted of the fruits set under high temperatures. For determination of percentage parthenocarpy and fruit quality analysis, the same procedures outlined previously in the Field Experiment were followed.

As in the Field Experiment, paired t-tests were done on fruit size, pH and SS between seeded and seedless fruits.

RESULTS AND DISCUSSION

GROUP I EXPERIMENTS:

FIELD EXPERIMENT.- To determine which varieties offer the best potential as parental material in a breeding program for parthenocarpy, 15 genetically parthenocarpic varieties were scored for gross morphological characteristics. These data are presented in Table 2. Three varieties ('Bubjekosoco', 'Priora' and '557') had indeterminate growth habit; this is reflected in vine size, as all three had vine diameters in excess of 100 cm 78 days after transplanting (DAT). 'Bubjekosoco' and 'Oregon T5-4' stood out as having better vine cover than the other varieties. 'Heinemanns Jubilaum', 'Oregon 11' and 'Severianin' tended to have fasciated fruits.

The varieties which flowered earliest were 'Oregon 11' (9 DAT), 'Farthest North' (10 DAT), 'BL 6807' (11 DAT) and 'Atom' (11 DAT) (Table 3). '557', 'Severianin' and 'Saladette' were the latest varieties, flowering aproximately 12 days later. Breaker-stage fruits were observed first in the varieties '(AxB)' and 'BL 6807' (59 DAT). 'Saladette', 'Severianin', '557' and 'Heinemanns Jubilaum' required 74 days or more to reach that stage.

Table 2 .- Gross morphological characteristics of fifteen tomato varieties. Davis 1984.

Variety	Green shoulder 1/	Fruit shape 2/	Concentration of fruits 3/	Growth habit 4/	Vine size (cm)	Leaf cover 5/	Po or U 6/	Other observations
Rubjekosoco (B)	+	R	Poor	I	126.8	G	Po	bushy, large vine
Heinemanns Jubilaum (HJ)	+	R	Regular	D	34.8	M	U	fasciated fruits
Priora (P)	+	RB	Regular	I	102.7	M	Po	
Atom (A)	-	R	Regular	D	36.5	P	Po	
A x B	-	R	Regular	D	44.2	P	Po	
(AxB) x (PxHJ)	-	R	Poor	D	44.2	P	Po	
75/59	-	R	Regular	D	61.7	P	Po	
BL 6807	+	R	Regular	D	42.2	P	Po	some blocky fruits
Oregon 11	+	R	Regular	D	59.7	P	Po/U	fasciation and cracking of fruits
Farthest North	+	R	Regular	D	49.0	P	U	high flower production but low fruit set
557	+	RF	Poor	I	115.3	M	Po	
Oregon T5-4	-	R	Regular	D	67.0	G	U	pink fruits, radial cracks, different types of plants
Oregon Cherry	+	R	Regular	D	96.8	M	Po	
Severianin	+	RF	Regular	D	69.3	P	U	fasciated fruits
Saladette	-	RB	Regular	D	62.5	P	U	

1/ += presence, -= absence
2/ R= round, RB= round blocky, RP= round flat
3/ Poor= all fruit stages, Regular= 50% or less of ripe fruit, Good= about 75% of ripe fruit
4/ I= indeterminate, D= determinate
5/ G= good, M=medium, P= poor
6/ Po= postrate plant, U= upright plant

Table 3.- Mean number of days from transplanting to flowering, initiation of fruit ripening and first harvest of fifteen tomato varieties. Davis, 1984.

Variety	Flowering	Fruit ripening	First harvest
Bubjekosoco (B)	15 ± 2*	64 ± 3*	98
Heinemanns Jubilaum (HJ)	13 ± 1	74 ± 5	87
Priora (P)	13 ± 1	65 ± 4	88
Atom (A)	11 ± 0	69 ± 1	94
A x B	12 ± 0	59 ± 2	95
(AxB) x (PxHJ)	13 ± 1	64 ± 4	96
75/59	16 ± 2	60 ± 3	87
BL 6807	11 ± 1	59 ± 2	83
Oregon 11	9 ± 1	65 ± 7	84
Farthest North	10 ± 0	62 ± 2	88
557	22 ± 2	76 ± 5	97
Oregon T5-4	16 ± 2	61 ± 6	97
Oregon Cherry	14 ± 2	62 ± 3	98
Severianin	24 ± 3	78 ± 7	95
Saladette	23 ± 2	80 ± 1	101

*= means of 30 plants ± standard deviation.

The highest total yields in terms of fresh fruit were observed in the varieties '557' (3.9 kg/plant), 'Bubjekosoco' (3.8 kg/plant) and 'Priora' (3.4 kg/plant) (Table 4). 'BL 6807' and 'Atom', each with 0.5 kg/plant, recorded the lowest yields.

Wide variation was observed between varieties in the capacity to develop parthenocarpic fruits (Table 4). At the first harvest, the percentage of parthenocarpy ranged from 0 to 88.5%; 'BL 6807', 'Oregon 11', 'Oregon T5-4' and '75/59' had the highest values, all exceeding 40%. At the second harvest, the expression of parthenocarpy was similar, from 0 to 90%. Generally, varieties had similar percentages of parthenocarpy at the two harvests; however, 'Oregon 11' and 'Severianin' had significantly higher percentages of parthenocarpy at harvest 1 than harvest 2. Also, 'Farthest North', 'Heinemanns Jubilaum', 'BL 6807' and 'Oregon T5-4' tended to have greater degrees of parthenocarpy at harvest 1 than harvest 2. This greater tendency for parthenocarpy may have been due to lower temperatures early in the season (see Appendices 1 and 2). Suprisingly, the reverse occurred in 'Atom' with a significantly greater percentage of parthenocarpic fruits at harvest 2 than harvest 1. The varieties, '75/59', 'Oregon 11' and 'Oregon T5-4', showed high degrees of parthenocarpy at both harvests, while '(AxB) x (PxHJ)', 'Bubjekosoco', 'Priora', '557', 'Oregon Cherry'

Table 4.- Total yield (kg/plant), number of fruits per plant, fruit size (g/fruit) and percentage of parthenocarpy of fifteen tomato varieties. Field experiment, Davis 1984.

Variety	Total Yield	Number of fruits H1	Number of fruits H2	Fruit size H1 +	Fruit size H1 -	Fruit size H2 +	Fruit size H2 -	Percentage of parthenocarpy H1	Percentage of parthenocarpy H2
Bubjekosoco (B)	3.8	48.3	136.6*	18.0	8.9*	12.3	6.1*	1.3	1.0
Heinemanns Jubilaum (HJ)	0.7	5.0	7.0	68.1	33.8*	58.5	12.0*	15.7	4.2
Priora (P)	3.4	8.3	39.0*	38.8	-	37.6	19.3*	0.0	3.9
Atom (A)	0.5	27.7	10.2*	12.6	5.0*	10.5	4.1*	8.8	38.1*
A x B	0.7	18.1	24.5*	18.1	14.9*	17.3	13.2	14.4	24.1
(AxB) x (PxHJ)	1.9	23.7	13.7*	42.6	28.5*	37.4	19.5*	14.3	15.5
75/59	0.8	21.2	19.7	21.7	17.9	16.9	13.1	88.5	90.0
BL 6807	0.5	13.3	17.2	20.5	9.8*	12.9	7.6*	40.5	28.8
Oregon 11	0.7	13.4	25.7*	20.3	18.4	14.5	14.1	74.5	54.1*
Farthest North	0.6	32.7	51.8*	6.3	3.2*	6.0	3.4*	15.1	7.8
557	3.9	10.1	30.2*	83.1	30.8*	64.8	18.7*	1.7	0.4
Oregon T5-4	1.4	39.8	37.1	12.3	12.4	12.2	7.4	80.2	60.4
Oregon Cherry	2.8	83.7	123.0*	10.7	4.9*	9.4	3.6*	3.4	6.8
Severianin	2.2	8.2	9.4	95.9	77.7*	102.3	68.9	30.0	4.2*
Saladette	2.1	15.2	17.9	50.3	17.8*	55.8	-	1.3	0.0

H1 and H2 indicate first and second harvest, respectively.
+= seeded fruit -=seedless fruit
*= pairs which are significantly different at 5% level.

and 'Saladette' showed very poor capacity to set parthenocarpic fruits at both harvests.

Fruit size of seeded fruits varied from 6.3 to 95.9 g and from 6.0 to 102.3 g at the first and second harvest, respectively (Table 4). Seedless fruits had smaller size than seeded fruits, in general. Seedless fruits fluctuated from 3.2 to 77.7 g at the first harvest and from 3.4 to 68.9 g at the second one. Possible exceptions may be 'Oregon 11' and 'Oregon T5-4'.

Within varieties, the percentage of soluble solids (SS) tended to be similar at harvest 1 and harvest 2 (Table 5); values varied considerably among varieties and between seeded and seedless fruits. There were no consistent differences in SS between seeded and seedless fruits. In some varieties parthenocarpic fruit showed greater SS than seeded fruits (e.g. 'Oregon 11', 'Farthest North'); in other cases, seeded fruits had greater SS than seedless ones (e.g. 'Atom', '(AxB)'). The same pattern was observed for pH values (Table 5).

GREENHOUSE EXPERIMENT: The highest yielding varieties in the greenhouse were '75/59' (2.4 kg/plant), 'AxB' (2.2 kg/plant) and '(AxB) x (PxHJ)' (2.0 kg/plant). As in the field, 'BL 6807' had the lowest yield (0.3 kg/plant) (Table

Table 5.- Soluble solids (%) and pH of seeded (+) and seedless (-) fruits of fifteen tomato varieties. Field experiment, Davis 1984.

Variety	Soluble solids				pH			
	H1		H2		H1		H2	
	+	-	+	-	+	-	+	-
Bubjekosoco (B)	6.96	7.24	6.78	6.23	4.47	4.20	4.57	-
Heinemanns Jubilaum (HJ)	5.67	5.62	5.70	8.00	4.26	4.20	4.32	-
Priora (P)	7.04	-	7.01	6.95	4.43	-	4.47	-
Atom (A)	5.84	5.35	5.77	5.68	4.34	-	4.44	-
A x B	6.00	5.67	5.94	5.41	4.24	4.37*	-	4.46
(AxB) x (PxHJ)	6.56	6.70	6.22	5.81	4.20	4.24	4.32	4.30
75/59	5.28	5.29	6.02	5.62	4.14	4.26*	-	4.41
BL 6807	6.34	6.15	7.18	7.37	4.30	4.25	4.45	4.50
Oregon 11	7.34	7.99	8.28	9.03	4.06	3.91*	4.33	4.37
Farthest North	8.19	8.40	7.89	8.97	4.17	4.20	4.30	4.25
557	7.10	8.12	6.80	7.50	4.45	-	4.55	-
Oregon T5-4	9.32	9.79	8.55	9.78*	4.43	4.50*	4.22	4.48*
Oregon Cherry	8.35	9.05	7.64	7.86	4.22	-	4.22	-
Severianin	5.72	5.67	5.52	6.04	4.15	4.11	4.30	4.10
Saladette	5.15	5.03	5.41	-	4.34	-	4.36	-

H1= first harvest H2= second harvest
*= indicate pairs which are significantly different at 5% level.
Some values are not included because that type of fruit was not produced or not enough fruits were available to prepare the samples.

6).

The yields observed in the greenhouse differed considerably from those observed under field conditions. 'Atom', 'AxB', '(AxB) x (PxHJ)', '75/59', 'Oregon 11' and 'Farthest North' had greater yields in the greenhouse experiment than in the field experiment. This was due basically to a greater production of fruits. Factors such as windy conditions or daily temperature fluctuations prevalent in the field may have contributed to their low yields under field conditions. In addition, their capabilities to set fruit under extremely high temperatures also have to be considered.

In the greenhouse, the capacity to set parthenocarpic fruits differed markedly between the two temperatures used. In the first harvest, which included fruits set under the normal temperature regime, the varieties 'Bubjekosoco', 'Heinemanns Jubilaum', '557', 'Oregon Cherry' and 'Severianin' did not set any seedless fruit. 'Priora', 'Atom', 'Oregon 11', 'Farthest North' and 'Saladette' had very low percentages of parthenocarpic fruits, ranging from 1.1 to 9.8%. The remaining five varieties showed considerable ability to set seedless fruits, especially '75/59' (96.6%). Extremely high temperatures caused a large increase in the production of seedless fruits (Table 6). At

Table 6.- Total yield (kg/plant), number of fruits per plant, fruit size (g) and percentage of parthenocarpy of fifteen tomato varieties. Greenhouse experiment, Davis 1984.

Variety	Total yield	Number of fruits		Fruit size				Percentage of parthenocarpy	
		H1	H2	H1		H2		H1	H2
				+	-	+	-		
Bubjekosoco (B)	0.8	6.7	21.6*	27.8	-	22.7	17.9*	0.0	1.9
Heinemanns									
Jubilaum (HJ)	0.6	4.6	6.8*	46.7	-	44.6	-	0.0	0.0
Priora (P)	1.5	24.3	38.7*	25.4	16.2*	19.8	11.2*	8.2	69.7*
Atom (A)	1.3	15.0	49.8*	27.3	20.9	19.6	10.1*	9.8	83.1*
A x B	2.2	24.5	72.6*	32.0	25.2	-	15.0	79.4	100.0*
(AxB) x (PxHJ)	2.0	8.8	25.8*	50.8	40.9	48.7	28.8	56.8	95.2
75/59	2.4	22.0	103.4*	33.5	23.7	-	12.5	96.6	100.0
BL 6807	0.3	16.8	16.3	10.5	8.9	11.5	8.0	41.3	97.6*
Oregon 11	1.7	23.1	85.8	20.4	12.2	14.3	11.8	9.7	76.2*
Farthest North	0.9	49.1	82.3*	9.3	3.6*	6.2	2.5*	1.1	7.8
557	1.0	5.1	6.4	93.8	-	64.6	59.5	0.0	46.5*
Oregon T5-4	0.7	15.7	38.1*	16.2	15.0	14.5	5.7*	35.0	77.9*
Oregon Cherry	1.6	22.7	79.8*	18.0	-	11.3	6.1*	0.0	5.5
Severianin	2.0	2.4	10.8*	147.0	-	103.0	115.8	0.0	54.8*
Saladette	1.5	3.3	21.3*	36.2	6.2*	36.4	26.2	7.6	15.2

H1= first harvest H2= second harvest; +=seeded fruit -= seedless fruit
*= pairs which are significantly different at 5% level

the second harvest, which included fruits set under high temperature, all of the varieties showed a certain degree of parthenocarpy with the exception of 'Heinemanns Jubilaum' which produced only seeded fruits. Eight varieties ('Priora', 'Atom', 'AxB', 'BL 6807', 'Oregon 11', '557', 'Oregon T5-4' and 'Severianin') set significantly higher percentages of parthenocarpic fruits at harvest 2 than harvest 1.

Most varieties expressed similar degrees of parthenocarpy under low and high temperatures (Field harvest 1 vs Greenhouse harvest 2). 'Priora', 'Atom' 'AxB' and '(AxB) x (PxHJ)' are exceptions. All four expressed little parthenocarpy at the first field harvest, but a high degree at the second greenhouse harvest. This would suggest that these varieties are temperature dependent for the expression of parthenocarpy. Several varieties demonstrated high degrees of parthenocarpy regardless of the environment. The varieties '75/59' and 'BL 6807' had high precentages of parthenocarpy at all four harvests.

Bagget and Frazier (1978a, 1978b, 1982) reported that 'Oregon T5-4', 'Oregon Cherry' and 'Oregon 11' were capable of setting parthenocarpic fruits under cool summer conditions. In this study 'Oregon T5-4' and 'Oregon 11' expressed high degrees of parthenocarpy under all conditions

(except for 'Oregon 11' under the normal temperature regime in the greenhouse). 'Oregon Cherry' showed very little parthenocarpy, however. Philouze (1985) commented that 'Oregon T5-4' showed little capacity for parthenocarpy. She also concluded that 'Sub Artic 'Plenty' ('BL 6807') expressed limited parthenocarpy. In this study, 'BL 6807' produced a large proportion of seedless fruits particularly at high temperatures. Likewise, El Ahmadi and Stevens (1979) reported 'BL 6807' to show a high degree of parthenocarpy at high temperatures. It is clear that temperature is influencing the expression of parthenocarpy in the tomato varieties evaluated; however, other factors may also affect this trait. These include the developmental stage of the plant during fruit set, vibration of flowers and the period of time under each temperature regime. Clearly, there are environmental factors which affect the expression of parthenocarpy which remain unexplained.

Fruit size, in general, was greater in the seeded fruits than in the seedless ones (Table 6), and basically, the fruits were larger in the first harvest than in the second one. There was one case where the seedless fruits were heavier than their seeded counterparts; in the second harvest, 'Severianin' seedless fruits weighed, on average, almost 13g more than the seeded fruits.

Like in the field experiment, the percentage of soluble solids (SS) and pH values were variable depending on the variety and harvest (Table 7). In the first harvest, SS ranged from 4.71 to 8.16 in seeded fruits and from 4.85 to 8.27 in seedless fruits. The values for the second harvest varied from 4.7 to 8.48 in seeded fruits and in seedless fruits from 4.11 to 9.38. There was no consistent trend for seeded or seedless fruits to have higher SS. The pH values were similar among the tomato varieties, between harvests and between seeded and seedless fruits (Table 7).

Taking into account the results of both the field and greenhouse experiments, it appears that 'Severianin' may have the best potential as parental material for a breeding program for parthenocarpy. Although this variety showed only a moderate expression of parthenocarpy, its yield and fruit size were among the highest. The varieties '75/59', 'Oregon T5-4' and 'BL 6807', which showed high degrees of parthenocarpy and were earlier than 'Severianin', can still be considered as parental material; however, they would require more breeding work since their fruit size is very small and their yields, particularly 'BL 6807', were among the lowest.

Table 7.- Soluble solids (%) and pH of seeded (+) and seedless (-) fruits of fifteen tomato varieties. Greenhouse experiment. Davis 1984.

Variety	Soluble solids				pH			
	H1		H2		H1		H2	
	+	-	+	-	+	-	+	-
Bubjekosoco (B)	5.11	-	5.56	5.35	4.23	-	4.38	-
Heinemanns Jubilaum (HJ)	4.71	-	5.56	-	4.13	-	4.10	-
Priora (P)	5.22	5.12	5.72	5.36	4.15	-	4.17	4.18
Atom (A)	5.13	5.10	5.29	5.18	4.10	-	4.22	4.23
A x B	5.66	4.85*	-	4.11	4.15	4.08	-	4.25
(AxB) x (PxHJ)	5.96	5.44	5.70	5.93	4.14	3.97*	4.07	4.13
75/59	6.18	5.23	-	4.33	-	4.15	-	4.25
BL 6807	6.29	6.06	6.63	6.73	4.43	4.30	-	4.43
Oregon 11	7.24	8.02	7.74	7.31	4.08	-	4.03	3.97
Farthest North	6.65	5.90*	6.74	6.48	4.01	-	4.00	4.00
557	5.98	-	6.87	6.67	4.31	-	4.35	4.43
Oregon T5-4	8.16	8.27	8.48	9.38	4.22	4.25	4.40	4.40
Oregon Cherry	6.05	-	6.65	5.80	4.03	-	4.10	4.20
Severianin	5.23	-	5.79	5.70	4.17	-	4.21	4.11
Saladette	-	-	4.70	-	-	-	4.25	-

H1= first harvest H2= second harvest
*= pairs which are significantly different at 5% level.
Some values are not included because no fruit of that type was produced or not enough fruits were available to prepare the samples.

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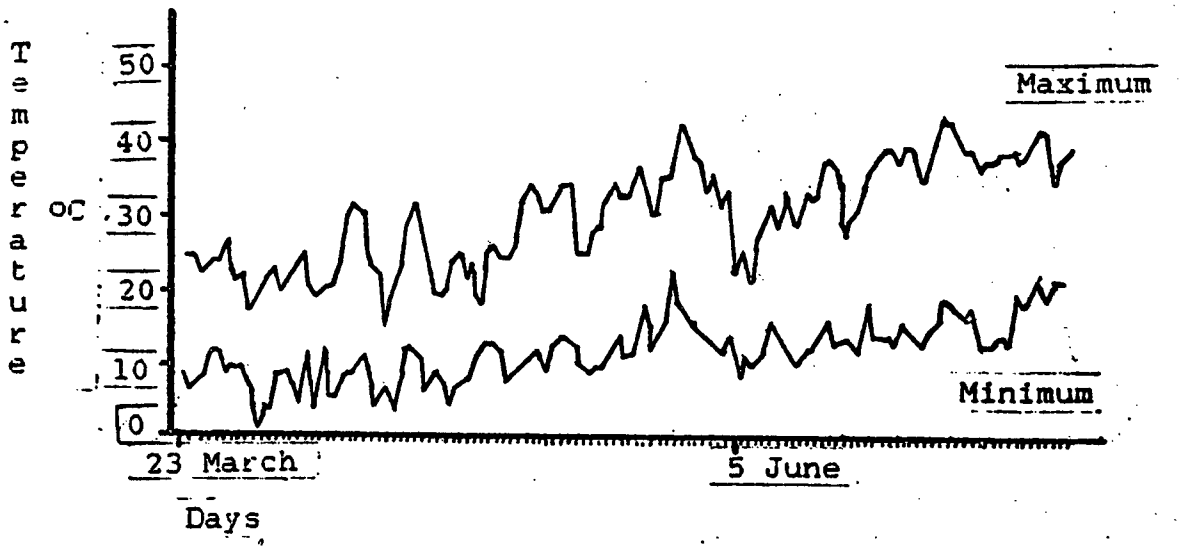
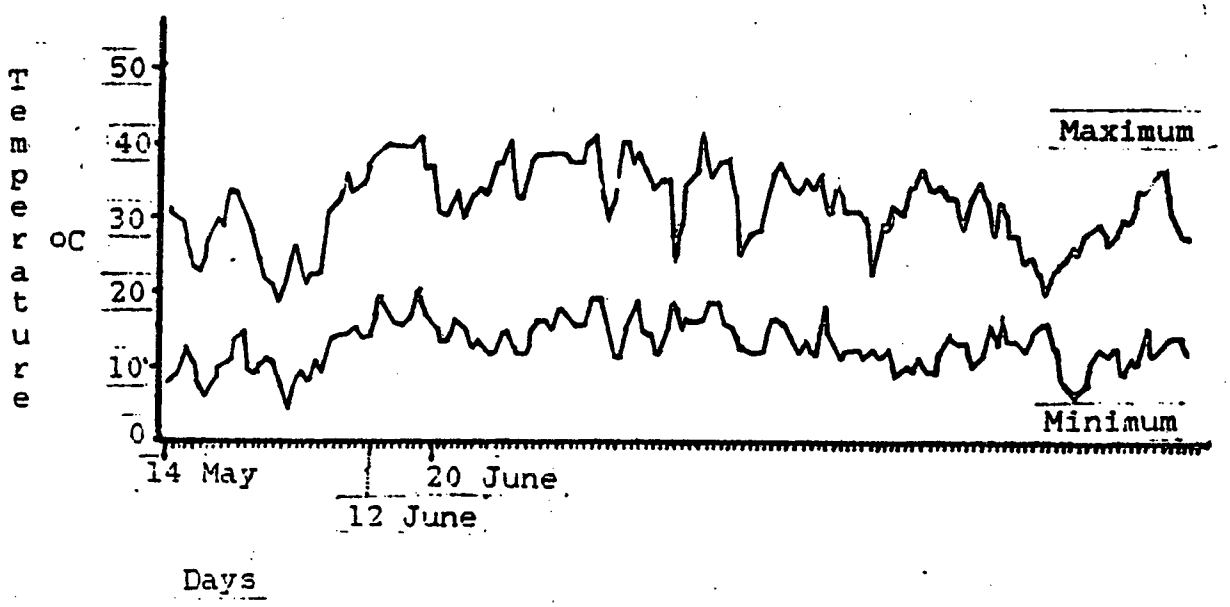
A P P E N D I C E S

Appendix 1.- Maximum and minimum temperatures in the field during 1984 and 1985.





Appendix 2.- Mean developmental stage(1) of the first and third flower cluster and average date of flowering of fifteen tomato varieties.

Variety	Developmental stage FC 24 DAT	TC 38 DAT*	Flowering date
Bubjekosoco (B)	2.5 ± 0.7	2.6 ± 1.1	7 April ± 2**
Heinemanns Jubilaum (HJ)	5.1 ± 0.8	6.0 ± 0.2	5 April ± 1
Priora (P)	3.2 ± 0.9	2.9 ± 1.2	5 April ± 1
Atom (A)	5.7 ± 0.8	4.6 ± 0.3	3 April ± 0
A x B	5.1 ± 0.7	5.9 ± 0.2	4 April ± 0
(AxB) x (PxHJ)	3.9 ± 0.9	5.8 ± 0.4	5 April ± 1
75/59	4.5 ± 0.8	5.8 ± 0.4	8 April ± 2
BL 6807	5.8 ± 0.4	2.9 ± 1.4	3 April ± 1
Oregon 11	5.9 ± 0.4	6.0 ± 0.0	1 April ± 1
Farthest North	5.9 ± 0.3	6.0 ± 0.0	2 April ± 0
557	0.9 ± 0.6	0.3 ± 0.5	14 April ± 2
Oregon T5-4	4.1 ± 0.6	5.8 ± 0.4	8 April ± 2
Oregon Cherry	5.4 ± 0.7	5.8 ± 0.4	6 April ± 2
Severianin	1.9 ± 1.3	3.5 ± 2.4	16 April ± 2
Saladette	3.3 ± 1.0	5.3 ± 1.1	15 April ± 2

(1) The scale used was as follow: 0= flower cluster is not observed, 1= flower cluster is noticeable but the number of flowers is difficult to count, 2= number of flower per cluster are easy to count, 3= flower cluster totally developed, individual flowers near to anthesis, petals are observable, 4=at least one flower in anthesis, but less than 50% of the flowers per cluster are opened, 5= more than 50% but less than 75% of the flowers per cluster are already in anthesis, 6= more than 75% of the flowers per cluster are in anthesis.
FC and TC indicate first and third flower cluster, respectively.
* = days after transplanting, ** = mean ± standard deviation

Appendix 3.- Sample preparation for quality analysis.

Each category of fruit, seeded or seedless, was ground in a Waring blender for one minute . One sample of the puree obtained was used to measure pH with a Beckman SS-2 pH meter while another sample was filtered. The resulting serum of the filtration was used for soluble solids determinations with a Bausch and Lomb Abbey refractometer, maintained at 20oC with a temperature bath. For the 1984 and 1985 experiments a similar procedured was followed. Once the puree was obtained, a pulper was used to remove seeds and skins. Two samples of this puree were taken. One sample was used for total solids determinations on a CEM AVC 80 microwave. The second sample was deaerated in a vacuum flask with a vacuum pump. The deaerated sample was divided into two subsamples. One subsample was filtered and the resulting serum was used for soluble solids determinations in the same way mentioned before. The second subsample was used for color determinations on a Agtrom M-500-A color instrument. After the color readings, the same sample was used for pH measurements and for titratable acidity. 10 ml of puree were titrated to pH 8.1 with 0.1 N NaOH. Furtheremore, water insoluble solids / total solids ratios, which give an idea of the consistency potential of processed tomato, were determined using the following formula:

$$WIS/TS = \frac{\%TS - \%SS}{\%TS}$$

OBJECTIVES, ACHIEVEMENTS AND BENEFITS TO AGRICULTURE

1. Genetic mapping of useful factors for parthenocarpy:

   The number of genes involved in parthenocarpy in the two most useful sources for tomato breeding has been determined and three genes have been resonably mapped; this will greatly facilitate breeding of parthenocarpic cultivars.

2. Synthesis of comparable parthenocarpic and normal lines:

   During the course of this study nearly isogenic lines have been produced to serve as study tools in physiology and development of parthenocarpic fruits; these lines are ready to be used to determine gene action of the different factors for parthenocarpy.

3. Determination of allelism of genes involved in parthenocarpy present in different sources:

   A first step has been taken to determine identity of factors involved in parthenocarpy from diverse sources; this will be of help for an efficient breeding program.

4. Evaluation of application of genetic parthenocarpy for the production of seedless tomatoes for processing:

   Significant higher solid and higher pH values in seedless tomatoes have been established in this study; this opens up the possibility to exploit these findings in breeding of parthenocarpic processing tomatoes for a higher solid yield.

5. Characterisation of potential parents for parthenocarpic tomatoes:

15 tomato varieties were evaluated as to the extent of parthenocarpy, plant characteristics and fruit quality traits; this survey provides for much useful information in study and breeding of parthenocarpic tomatoes.

Description of cooperation and publication of results

The program has been well coordinated by a clear outline of the division of labor. The U.S. group worked on the physiological and developmental aspects of the subject and the Israeli group on the genetic aspects. 3 meetings of the investigators to discuss and observe the program took place.

One paper resulting from the program is in press and two papers have been submitted for publication.