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Title: THE INHERITANCE OF PARTHENOCARPY IN TOMATO (LYCOPERSICON ESCULENTUM)

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A parthenocarpic breeding line, Oregon T5, from Oregon State University, was crossed with several commercial cultivars. Progenies were studied for 2 years as both direct-seeded plants and transplants in the field at Corvallis, Oregon to determine the inheritance of parthenocarpy in Oregon T5. Both quantitative and qualitative measurements of parthenocarpy were used.

F_1, F_2 and backcross data indicated that the inheritance of parthenocarpy in T5 is recessive. F_2 data fit a 9 seedy:7 seedless ratio, suggesting duplicate recessive genes.

F_2 data from a cross with 'Severianin', an unrelated parthenocarpic cultivar, indicated the inheritance of parthenocarpy in T5 is due to different genes than in 'Severianin'. These data also support the hypothesis of 2 genes for parthenocarpy in

T5, with a possible interaction of modifiers for parthenocarpy from both parents.

Chi square tests showed an association between parthenocarpy and earliness as measured by number of days to first ripe fruit. This earlier ripening in T5 crosses resulted from a shorter interval between flowering and ripening, and not from earlier flowering, in most cases. In general, no association was indicated between parthenocarpy and fruit size.

The Inheritance of Parthenocarpy in Tomato (*Lycopersicon esculentum*)

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THE INHERITANCE OF PARTHENOCARPY IN TOMATO (*LYCOPERSICON ESCULENTUM*)

INTRODUCTION

Parthenocarpy is defined as the formation of fruit without fertilization or the development of seeds. It is generally considered to be of 2 types: stimulative, in which pollination is required for fruit development but fertilization does not take place, and vegetative, in which neither pollination or fertilization are required for fruit development.

Some very early lines of tomatoes produce parthenocarpic (seedless) fruit at the beginning of the summer, then normal seedy fruit for the rest of the season. This characteristic is apparently temperature dependent; that is, parthenocarpic fruit are produced early in the season because temperatures are low. The ability to produce fruit under low temperature conditions should be useful in the development of early maturing tomatoes for cool climates.

The purpose of this study was to determine the inheritance of a parthenocarpic tendency in Oregon T5, a tomato cultivar developed at Oregon State University. Inconclusive tests indicate that this line requires pollination to set parthenocarpic fruit. Crosses were made between Oregon T5, which produces early parthenocarpic fruit in the field, and several commercial cultivars which produce no parthenocarpic fruit under field conditions. Parents, F_1, F_2 and backcross progeny for each cross were grown concurrently in the field and several measurements of parthenocarpy were recorded. Other characteristics of interest to tomato breeders, specifically earliness and fruit weight, were also recorded and studied for possible associations with parthenocarpy. It is hoped that this information will prove useful in the breeding of tomatoes for cool climates.

LITERATURE REVIEW

Cultivars with the Ability to Set Parthenocarpic Fruit

There are several reports in the literature of tomatoes which have the genetic ability to set parthenocarpic fruit. Lesley (14) reported that the commercial tomato (*Lycopersicum esculentum*) produces seedless fruits when pollinated with *Lycopersicum peruvianum*. Lesley and Lesley (15) obtained a line of aneuploid plants from a cross between two diploid plants which showed a tendency for parthenocarpy.

Much of the work with parthenocarpy in tomatoes has been done in Russia. Janusevic (11), and Janusevic and Ludnikova (18) described parthenocarpic cultivars from Kisinev and Pobeda (USSR). The authors report they were able to increase the percentage of parthenocarpic fruits from 30% to 70% by selection. In a detailed study on parthenocarpy in tomatoes, Ludnikova (17) reported a cultivar, 'Pridneprovsky', which was obtained by crossing *Lycopersicum esculentum* and *Lycopersicum cerasiforme*, and which sets seedless fruits with or without pollination. Maisonneuve (19) described the cultivar 'Severianin', obtained from a cross between *Lycopersicum esculentum* and *Lycopersicum* *hirsutum*, and reported that 'Severianin', without pollination, sets parthenocarpic fruit that are almost as large as the control seeded fruit.

There have also been reports of parthenocarpic cultivars from Germany (27) and Italy (31).

Physiology of Parthenocarpic Fruit Set

Early research into the physiology of fruit set led to efforts to explain parthenocarpy. Many early experiments led to the conclusion that the stimulus of growth which follows fertilization is hormonal in nature. In 1902 Massart (21) showed that dead pollen placed on the stigma of orchids caused a slight enlargement of the ovary. In 1935, Yasuda (34) injected an aqueous solution of cucumber pollen into cucumber ovaries and got several cucumbers of normal size but without seeds. Thimann (32) had shown that pollen contained auxin, and in 1936 Gustafson (7) used pure IAA, applied in a lanolin base to the styles of tomatoes, to produce parthenocarpic fruit.

More direct evidence of the role of growth regulators in fruit development comes from studies of the auxin content of ovaries before and after fertilization. It has been shown that the ovary before fertilization contains either very small amounts of free growth substances or none at all, but after fertilization, relatively large amounts of these substances may be extracted (33). Gustafson (8) further showed that the highest concentrations of growth substances are found in the developing ovaries, and Dolfus (5) showed that when the ovules of various plants were removed from the ovary after pollination, the growth that had begun stopped, but when the cavity was filled with IAA, nearly normal growth continued.

Gustafson (8) proposed the theory that some plants are able to set parthenocarpic fruit because of an abnormally high endogenous auxin content in the ovary. This theory has found support from other researchers. Ludnikova (16) found that the ovaries of unopened flower buds of the parthenocarpic tomato hybrid 'Pridneprovsky' contained a higher concentration of growth substances than did the ovaries of a non-parthenocarpic tomato cultivar. Similarly, Musehold (22) found that the young unpollinated ovaries of a parthenocarpic tomato cultivar had a higher content of free growth substances at the beginning of the flowering period than did those of 2 non-parthenocarpic cultivars, and also reached a somewhat higher maximum content later in the season.

Research has been done to determine why fertilization does not occur, and normal seeds do not develop, in parthenocarpic lines. Avakimova and Dovedar (1) observed that the ovules of a non-parthenocarpic tomato cultivar 'Vinegreen' were fertilized 30 hours after pollination, whereas 36 hours after pollination of the parthenocarpic cultivar 'Severianin' few pollen tubes had reached the ovary. Pollen tube growth stopped in the style of 'Severianin', and the authors noted a thickening of the ends. Avakimova and Dovedar also reported a difference in the free amino acid composition in the ovaries of the 2 cultivars; concentration of the amino acid 'phe' was high in the ovaries of 'Severianin', and non-existent in the ovaries of 'Vinegreen'. The authors suggest that the poor germination of selfed pollen in 'Severianin' may be due to this difference in the amino acid composition, and poor germination of pollen would, in turn, explain the absence of seeds.

Pollen of a parthenocarpic tomato cultivar, '65/107', was studied by Priel and Reimann-Phillip (27). They observed that germination of selfed pollen was identical to that of foreign pollen in the style of '65/107', and that pollen of '65/107' was able to fertilize the ovules of another cultivar and induce seed formation. Therefore, the authors concluded that in '65/107' it was not the failure of pollen formation or germination that was responsible for the absence of seed. They suggested that the growth of the ovary might be stimulated before fertilization by a high endogenous concentration of growth substances, so that, at anthesis, fertilization of the ovules would no longer be possible.

Expression of Parthenocarpy in Varying Environments

Specific environmental conditions are frequently associated with parthenocarpic fruit development. That environmental conditions can trigger natural production of parthenocarpic fruit in tomatoes has been shown by several investigators. Hawthorne (9) has described tomatoes that produced seeded fruits in early summer and in the fall, but seedless fruits during the hot part of the summer in Texas. Priel (26) found that low temperatures also increased parthenocarpy. His studies with a parthenocarpic tomato cultivar showed that at a constant day temperature of 25°C, night temperatures of 5°C, 10°C, and 20°C produced 71.2%, 45.0%, and 29.1% parthenocarpy, respectively. Production of parthenocarpic fruit at high and low temperatures is probably explained by the experiments of Dempsey (3), who found that at low temperatures the rate of pollen germination and tube growth is very slow, while at high temperatures percent pollen germination is low. Charles and Harris (2) reached a similar conclusion about fruit set at low temperatures, but suggested parthenocarpic fruit set at high temperatures was due to stigma exertion.

Other environmental conditions have also been found to influence the production of parthenocarpic fruit, including light intensity (23) and high humidity (29). It is currently held that environmental factors probably increase parthenocarpy by affecting the hormone content of the ovary, raising it above the level necessary for stimulation of fruit development. Rudich and coworkers (28), for example, demonstrated that short photoperiod increased the auxin activity in the ovaries of cucumbers which produced parthenocarpic fruit.

Chemical differences between seedless and seeded tomatoes have been reported by Janes (10), who found the acid content to be similar in both, but evenly distributed in seedless fruits while concentrated in the locules of seeded fruits, and by Richter (19), who found that seedless fruit generally contain more dry matter.

Several researchers have studied the relationship between earliness and parthenocarpy. Marre and Murneek (20) have shown that seeds, acting as centers of auxin production, control the metabolism of carbohydrates. Therefore, they conclude, fruits with many seeds have greater metabolic activity, accelerating cell enlargement and fruit development. However, Rylski (30), working with seeded, naturally seedless, and growth-regulator-induced seedless tomatoes, found no relationship between the number of seeds per fruit and the number of days required for fruit ripening, and Falavigna and co-workers (6), studying F_2 progenies from crosses between parthenocarpic and non-parthenocarpic tomato cultivars, found that the parthenocarpic genotypes were earlier than the seeded ones.

Inheritance

The inheritance of parthenocarpy has been studied in cucumber, with conflicting results. Pike and Peterson (25) and Juldasheva (12) found it to be governed by a single gene; however, Pike and Peterson concluded it was an incompletely dominant gene, whereas Juldasheva found it to be recessive. Other authors have found the inheritance of parthenocarpy in cucumber to be due to more than 1 gene. Kvasnikov (13) concluded it was governed by many incompletely recessive genes, while DePonti and Garretsen (4) found it could be explained by 3 independent major genes with additive action. Apparently, then, different genetic systems are responsible for parthenocarpy in different cucumber cultivars.

Recently, there have been several reports of studies on the inheritance of parthenocarpy in tomato. Soressi and Salamini (31) found that parthenocarpy in their material was due to a single recessive gene, for which they proposed the symbol pat. They reported that plants carrying this gene were high yielding and early, and had small fruit (20-42 grams). Similarly, Philouze and Maisonnueve (24), studying the cultivar 'Severianin' obtained from interspecific hybridization, also concluded that parthenocarpy was due to a single recessive gene. However, from an allelism test done with crosses between 'Severianin' and the parthenocarpic material from Soressi and Salami, the authors concluded that the parthenocarpic character in 'Severianin' was due to a mutation at a different locus to pat, and proposed the symbol pat-2 for this gene. Philouze and Maisonnueve also studied the parthenocarpic cultivar '75/59' supplied by Reimann-Phillip and concluded that the parthenocarpic character in '75/59' is not due to pat or pat-2, but rather is controlled by several recessive genes.

MATERIALS AND METHODS

1977 Study

A preliminary study done during the summer of 1977 used F_2 seed from crosses made previously between T5-4-1, inbred for 5 generations, and 3 non-parthenocarpic commercial cultivars, 'Saladmaster', 'Starshot' and 'Tiny Tim'. The crosses and their reciprocals (Table 1) were direct-seeded in the field at the Vegetable Research Farm on May 10, 1977. (No reciprocal seed was available for cross 1.)

The field received preplant fertilizer at the rate of 67.4 Kg N, 202.2 Kg P_2O_5, and 67.4 Kg K_2O per hectare. Plants were thinned to stand approximately 46 cm (1.5 feet) apart in the rows, with 183 cm (6 feet) between rows. A uniform stand was obtained. Sprinkler irrigation was applied as necessary for normal growth.

Individual plant data were taken at 2 day intervals, and were therefore accurate to within 1 day. Flowering date was considered to be the day the first flower opened, and first ripe fruit date the day the first normal size fruit was at edible stage. The first ripe fruit on each plant was cut open, and the presence or absence of seeds was recorded. If the first ripe

Table 1. Tomato crosses and backcrosses studied.[a]

Cross #	Parentage	Year
1	T5-4-1 x 'Saladmaster'	1977
2	T5-4-1 x 'Tiny Tim'	1977
3	T5-4-1 x 'Starshot'	1977
4	T5-4-3-2-1 x 'Starshot'	1979
5	T5-4-3-2-1 x 'Saladmaster'	1979
6	T5-4-3-2-1 x 'Willamette'	1979
7	Cross 4 F_1 x T5-4-3-2-1[b]	1979
8	Cross 4 F_1 x 'Starshot'[b]	1979
9	Cross 5 F_1 x T5-4-3-2-1[b]	1979
10	Cross 5 F_1 x 'Saladmaster'[b]	1979
11	Cross 6 F_1 x T5-4-3-2-1[b]	1979
12	Cross 6 F_1 x 'Willamette'[b]	1979
13	T5-4-3-2-1 x 'Severianin'	1980

[a] T5-4 sublines and 'Severianin' are parthenocarpic types; the remainder are normally seedy. T5-4-3-2-1 is designated T5 for this study.

[b] All 4 possible combinations were made in each case.

fruit was seedless, successive ripe fruit from the same plant were examined until the plant started producing seedy fruit, and the day of the first seedy ripe fruit was then recorded. Average fruit weight was determined by weighing 10 typical fruit per plant. Flowering date and average fruit weight data were taken for the first 100 plants only in each plot.

These data for the 1,302 individual plants comprising all 3 crosses were transferred to computer cards for tabulation of the 5 characteristics mentioned above, and investigation of possible relationships between them.

Also during the summer of 1977, data were taken to determine the percentage of seedlessness and length of the seedless period of several T5-4 sublines. This was done by harvesting all the ripe fruit on individual plants once a week for a period of 7 weeks and determining the percentage of parthenocarpic fruit each time. From these data (Table 2) it was determined that T5-4-3-2-1 had the overall highest percentage of parthenocarpic fruit, and remained seedless the longest, of the lines tested.

1979 Study

Because T5-4-1, the line originally used in crosses, had been inbred for only 5 generations

Table 2. Percentage of parthenocarpic fruit in T5-4 sublines, 1977.

Line	Percent Parthenocarpic on Dates:						
	8/3	8/11	8/16	8/22	8/29	9/6	9/12
T5-4-2-1-1	100	100	100	32	0	0	0
T5-4-2-1-2	100	100	0	0	0	0	0
T5-4-2-1-3	100	88	75	0	0	0	0
T5-4-2-1-4	100	100	50	0	0	0	0
T5-4-2-1-5	-	100	90	68	9	0	0
T5-4-2-1-6	-	100	92	46	12	7	0
T5-4-2-1-7	-	100	100	92	91	44	15
T5-4-2-1-8	-	-	98	25	0	0	0
T5-4-2-1-9	-	-	32	17	0	0	0
T5-4-2-5-1	100	100	100	0	0	0	0
T5-4-2-5-2	-	100	92	73	19	15	0
T5-4-2-5-2	-	-	94	7	0	0	0
T5-4-3-2-1	-	100	100	100	100	72	13
T5-4-3-2-2	-	100	82	7	0	0	0
T5-4-3-2-3	-	100	100	79	64	17	0
T5-4-3-2-4	-	-	99	6	0	0	0
T5-4-3-5-1	82	74	20	2	0	0	0
T5-4-3-5-2	-	91	12	0	0	0	0
T5-4-3-5-3	-	100	100	82	76	57	0
T5-4-3-5-4	-	100	85	30	26	14	0

and was not entirely uniform, and because it was not the line determined to display the greatest expression of parthenocarpy in the field, new crosses were made in the greenhouse in the winter of 1977-78 using T5-4-3-2-1 (hereafter designated T5), an F_7 line, as the parthenocarpic parent and 'Saladmaster', 'Starshot' and 'Willamette' as the non-parthenocarpic parents. 'Tiny Tim' was dropped as a parent because of problems with sterility in the greenhouse, and 'Willamette' was added because it is a large fruited cultivar. Individual plants of T5 were used to make the crosses; therefore, this parent could be considered to be the eighth generation. F_1 seed was obtained from these crosses and their reciprocals, some of which was planted in the greenhouse in the spring of 1978 and allowed to self-pollinate to obtain F_2 seed. Reciprocal backcrosses between the F_1 and each parent were also obtained by hand pollination. For all crosses in this study, P_1 designates the parthenocarpic (seedless) parent, P_2 the normal (seedy) parent, F_1 and F_2 designate parthenocarpic parent x normal parent, and F_1R and F_2R designate normal parent x parthenocarpic parent. For the backcrosses, BC_1 indicates F_1 x parthenocarpic parent, BC_2 indicates F_1 x normal parent, and the use of R indicates the reciprocals.

There were 14 populations, including reciprocals, for each of the 3 crosses available for the 1979 planting. Both transplants and direct-seeded plants were used. Transplants of each of the total of 42 populations were started in the greenhouse on April 3, 1979. Forty plants of each population were grown, with the exception of the F_2 and F_2R populations, of which 200 each were grown. In some cases fewer than these standard numbers of plants were grown due to limited seed supply. The transplants were established in the field on May 24 and 25, 1979. They were randomized in 4 replications, with 42 plots per replication and approximately 10 plants per plot for all populations except the F_2 and F_2R, which had 50 plants per plot. These plants were spaced approximately 46 cm (1.5 feet) apart in the rows.

The direct-seeded plots were planted on May 23, and arranged similarly, in 4 replications with 42 plots per replication and approximately 46 m (15 feet) per plot for all populations except the F_2 and F_2R, which were planted in 22.9 m (75 foot) plots. Plants were later thinned to stand approximately 46 cm (1.5 feet) apart, giving plant numbers per replication which were theoretically similar to those in the transplanted plots. In most cases, however, there were problems with poor stand in the direct-seeded plots, resulting in smaller total populations and some missing plots.

Cultural practices were as described earlier for the 1977 study.

Individual plant data were taken as in 1977, but with the following differences. Because of the large total number of plants involved, it was not possible to examine each plant at 2 day intervals; however, the data for first flower and first ripe fruit were accurate to within 2 or 3 days. After each plant had ripened its first seedy fruit, it was checked once a week and a note made as to whether ripening fruit were seedy or seedless on that date, until September 23, when all the plants in the field were ripening seedy fruit. Average fruit size data were taken only for the F_2 and F_2R plots of cross 6, the only cross with a commercial parent different than those in the 1977 study.

Parthenocarpic fruit set, therefore, was measured in several different ways, both quantitatively and qualitatively. The ability to set parthenocarpic fruit as measured by a plus or minus reading for the first ripe fruit on each plant and by similar readings for later fruits over the course of the summer, is a qualitative characteristic. It was found that the shift from parthenocarpic fruit production to production of normal seedy fruit was not always permanent; that is, some plants first produced seedy fruit, then shifted to seedless fruit, then back to seedy fruit, while other plants began producing seedless fruit, shifted to seedy fruit, reverted to seedlessness, then again produced seedy fruit. The reversions category is an attempt to characterize these observations. More than 1 reversion to seedlessness was not observed, and all plants were seedy by the end of the season. Reversions to seedlessness were not observed in the direct-seeded plants; therefore, the values for reversions are used only for the transplanted material from 1979. The reversions category proved valuable for descriptive purposes, but, because it was based on an arbitrary scoring system, was not used in statistical computations. The plus or minus classification of first ripe fruit, therefore, proved to be the most valuable qualitative measurement of parthenocarpy.

The other measurements of parthenocarpy used in this study, the total number of seedless days, and the number of days from planting date and from first ripe fruit to the date when the plant became permanently seedy, are all quantitative measurements. They were recorded for the 1979 study only. The number of days from planting to the date when the plant became permanently seedy proved to be unreliable as a measurement of parthenocarpy because maturity date complicated the data, and was therefore omitted. The number of days from first ripe fruit to the date when the plant became permanently seedy was a reliable measurement, but behaved statistically very much like total number of seedless days, a more readily understood measurement of parthenocarpy. Therefore, total number of seedless days proved to be the most useful quantitative measurement of parthenocarpy.

The other characteristics observed or measured, first flowering date, first ripe fruit date, and number of days from first flower to first ripe fruit as measurements of earliness, and fruit weight, were of interest in studying possible associations with parthenocarpic fruit set.

Data for the 3,560 individual plants were organized into 8 descriptive categories and transferred to computer cards. The categories used were as follows: first flower = the number of days from planting to first open flower; first ripe fruit = the number of days from planting to first fruit at edible stage; first flower to first ripe fruit = number of days from first open flower to first fruit at edible stage; parthenocarpic first fruit = a plus or minus classification of the first ripe fruit; reversions = a description of the tendency of some plants to shift from the production of parthenocarpic fruit to the production of seedy fruit, and vice versa; number of seedless days = the total number of days a plant ripened seedless fruit; first ripe fruit to permanently seedy = the number of days from date of the first ripe fruit to date plant became permanently seedy; and fruit weight = average weight in grams of a typical fruit.

Each characteristic was tabulated, and possible relationships were investigated. F_1 and F_1R populations for each cross were combined because of low plant numbers. F_2 and backcross populations were tested for reciprocal differences, using Chi square (χ^2) tests, and combined where Chi square values which were not significant at .01 probability indicated no differences existed (Table 3). Where differences did exist, reciprocal populations were used both separately and combined in all computations. Plot means were obtained for each of the 192 plots, after combining reciprocals as described above, and used in analysis of variance for further genetic analysis.

1980 Study

During the summer of 1980, F_2 seeds from a cross between T5 and 'Severianin', a Russian cultivar which also has the ability to set parthenocarpic fruit, were direct-seeded at the Vegetable Crops Farm. Cultural practices and data recording were as described for the other experiments. The data were analyzed to

Table 3. Chi square tests for reciprocal differences, 1979.[a]

Cross	Populations Compared[b]		Transplants n	Transplants Chi Square Values: First Ripe Fruit (4 d.f.)	Parthenocarpic First Fruit (1 d.f.)	Reversions (3 d.f.)	Total Number Seedless Days (5 d.f.)	Direct-Seeded n	Direct-Seeded Chi Square Values: First Ripe Fruit (3 d.f.)	Parthenocarpic First Fruit (1 d.f.)	Total Number Seedless Days (3 d.f.)
	F_2	F_2R	393	3.92	1.15	8.97*	5.76	168	3.77	1.59	5.38
4	P_1xF_1	F_1xP_1	79	7.60	0.002	6.95	6.46	24	1.70	0.22	2.85
T5 x 'Starshot'	P_1xF_1R	F_1RxP_1	70	3.76	0.56	1.65	4.92	23	0.68	0.00	2.73
	BC_1	BC_1R	149	5.98	0.62	3.57	1.01	52	2.25	2.59	4.38
	P_2xF_1	F_1xP_2	68	2.89	0.00	0.00	0.00	29	2.36	0.01	0.51
	P_2xF_1R	F_1RxP_2	79	5.36	0.00	0.00	0.00	41	2.58	0.20	1.29
	BC_2	BC_2R	147	8.96	0.00	0.00	0.00	70	2.24	0.95	2.90
	F_2	F_2R	397	11.19*	0.001	7.45	11.30*	201	5.46	0.07	2.72
5	P_1xF_1	F_1xP_1	47	1.95	0.51	1.34	8.98	21	2.86	2.45	2.01
T5 x 'Saladmaster'	P_1xF_1R	F_1RxP_1	38	1.30	0.13	5.68	5.83	21	-	-	-
	BC_1	BC_1R	05	3.05	2.69	4.03	6.23	42	0.10	2.74	6.18
	P_2xF_1	F_1xP_2	72	2.10	0.00	0.00	0.00	29	2.09	1.55	1.55
	P_2xF_1R	F_1RxP_2	71	3.84	1.52	1.52	1.52	32	5.24	3.20	3.20
	BC_2	BC_2R	143	7.40	0.00	0.00	0.00	61	3.54	0.30	0.30
	F_2	F_2R	396	5.38	2.14	11.76**	5.30	191	0.75	3.11	5.46
6	P_1xF_1	F_1xP_1	47	5.78	1.50	2.25	5.42	20	-	-	-
T5 x 'Willamette'	P_1xF_1R	F_1RxP_1	52	9.41	2.58	2.04	8.82	27	4.89	1.44	3.77
	BC_1	BC_1R	99	1.47	1.07	3.65	9.26	47	0.23	0.05	0.02
	P_2xF_1	F_1xP_2	60	6.82	0.00	0.00	0.00	26	2.03	0.00	0.00
	P_2xF_1R	F_1RxP_2	54	1.22	0.00	0.00	0.00	16	-	-	-
	BC_2	BC_2R	114	8.21	0.00	0.00	0.00	42	0.05	1.53	1.53

[a]Where no Chi square values are listed, one of the populations was too small to test.

[b]Explanation of symbols: P_1 = T5, P_2 = commercial parent, F_1 and F_2 = T5 x seedy parent, F_1R and F_2R = seedy parent x T5, $BC_1 = F_1$ x T5, $BC_2 = F_1$ x seedy parent

*significant at .05 probability **significant at .01 probability determine if the inheritance of parthenocarpy is due to the same genetic system in the 2 parents.

RESULTS AND DISCUSSION

1977 Study

Table 4 summarizes the data collected on all characteristics for the parents and F_2 populations of the 3 tomato crosses planted in 1977. There was little variation in flowering date for the 4 parents used, but notable differences in first ripe fruit date, with T5-4-1 ripening earlier than the 3 commercial parents. All 11 T5-4-1 plants had parthenocarpic first ripe fruits, while all the other parents had seedy first ripe fruit. There was a large difference in fruit weight for the 2 parents of 1 cross, T5-4-1 and 'Starshot', with 'Starshot' being larger than T5-4-1.

The F_2 populations also showed little variation in flowering date, and differed little from the parents in this variable. Date of first ripe fruit showed less variation in the F_2 populations than it did in the parents, and was always between the 2 parental extremes. The frequency of parthenocarpic first ripe fruit in the F_2 populations varied from 13% in cross 1 to 40% in cross 3R. In all cases, the frequency of parthenocarpic fruit in the F_2 was less than 50%, indicating that parthenocarpy in this material is not dominant. Crosses 2, 2R, and 3 showed a good fit when

Table 4. Statistical parameters for parents and F_2 populations based on individual plant data, 1977.

Variable	Parameter	Parents				Cross [a]				
		'Saladmaster'	'Tiny Tim'	'Starshot'	T5-4-1	1	2	2R	3	3R
First [b] Flower	Minimum	51	48	50	50	50	47	47	48	48
	Maximum	59	58	59	52	60	58	56	56	61
	Mean	54.13	51.41	52.17	50.55	52.72	50.16	50.28	51.26	52.35
	Std. Dev.					2.09	2.16	1.69	1.76	2.21
First [b] Ripe Fruit	Minimum	100	95	97	79	88	85	78	79	83
	Maximum	118	101	108	90	120	118	99	101	119
	Mean	107.88	97.88	100.45	83.58	99.17	94.29	92.12	91.01	92.84
	Std. Dev.					4.52	3.60	3.45	4.29	4.98
Fruit Weight (grams)	Minimum					20	12	10	33	40
	Maximum					76	52	56	99	99
	Mean	89	22	240	28	45.07	27.35	27.01	64.48	71.47
	Std. Dev.					11.82	8.03	9.67	18.07	16.50
Partheno-carpic First Ripe Fruit	No. Fruit Examined	24	17	29	11	319	349	110	203	321
	% Partheno-carpic	0	0	0	100	13	23	26	21	40
	Chi Square						0.70 [c]	0.05 [c]	1.84 [c]	2.05 [d]

[a] Cross 1 = T5-4-1 x 'Saladmaster', Cross 2 = T5-4-1 x 'Tiny Tim', Cross 2R = 'Tiny Tim' x T5-4-1, Cross 3 = T5-4-1 x 'Starshot', Cross 3R = 'Starshot x T5-4-1'.

[b] Number of days from May 10 planting date.

[c] Tested against a 3:1 ratio; all values non-significant at .05 probability.

[d] Tested against a 9:7 ratio; all values non-significant at .05 probability.

tested against a genetic ratio of 3 seedy:1 seedless using Chi square tests, which would indicate parthenocarpy is due to a single recessive gene. However, cross 3R, which showed greatest expression of parthenocarpy in 1977, most closely fits a genetic ratio of 9 seedy:7 seedless, suggesting duplicate recessive genes.

Relationships, determined by Chi square tests, between parthenocarpy and date of first flower, first ripe fruit date, and fruit weight are shown in Tables 5-7. Significant Chi square values indicate a strong association between parthenocarpy and first ripe fruit date in all crosses. The parthenocarpic fruit ripened significantly earlier than the seedy fruit, an indication that seedless fruit may develop faster than seedy fruit. There was little or no association between parthenocarpy and date of first flower, or between parthenocarpy and fruit weight, even though the 2 parents of cross 3 differed greatly in fruit size.

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Tables 8-10 summarize the data obtained for 3 tomato crosses, both transplants and direct-seeded plants, during the summer of 1979. For both of the qualitative measures of parthenocarpy, the plus or minus reading on the first ripe fruit and the reversions category,

Table 5. Chi square values for the relationship of parthenocarpic first ripe fruit to first flower date in F_2 populations, 1977.

Cross	Parthenocarpic First Ripe Fruit	Number of Plants							
		Observed			Expected			Total	χ^2 [a]
	Days[b]	50-52	52-54	54-60	50-52	52-54	54-60		
1	Yes	5	4	1	2.8	4.4	2.7	10	
(T5-4-1 x	No	22	38	25	24.2	37.6	23.3	85	
'Saladmaster')	Total	27	42	26	27	42	26	95	3.04
	Days[b]	44-48	48-52	52-60	44-48	48-52	52-60		
2	Yes	1	16	5	2.4	14.0	5.6	22	
(T5-4-1 x	No	10	47	20	8.6	49.0	19.4	77	
'Tiny Tim')	Total	11	63	25	11	63	25	99	1.54
	Days[b]	47-50	50-53	53-56	47-50	50-53	53-56		
2R	Yes	9	16	2	8.5	16.6	1.9	27	
('Tiny Tim' x	No	22	45	5	22.5	44.4	5.1	72	
T5-4-1)	Total	31	61	7	31	61	7	99	0.09
	Days[b]	48-50	50-52	52-56	48-50	50-52	52-56		
3	Yes	1	5	11	2.6	6.7	7.7	17	
(T5-4-1 x	No	14	33	33	12.4	31.3	36.3	80	
'Starshot')	Total	15	38	44	15	38	44	97	3.43
	Days[b]	48-51	51-54	54-63	48-51	51-54	54-63		
3R	Yes	6	20	14	7.6	23.0	9.3	40	
('Starshot' x	No	13	37	9	11.4	34	13.7	59	
T5-4-1)	Total	19	57	23	19	57	23	99	5.21

[a]All values non-significant at .05 probability. [b]Number of days from planting to first flower.

Table 6. Chi Square values for the relationship of parthenocarpic first ripe fruit to first ripe fruit date in F_2 populations, 1977.

Cross	Parthenocarpic First Ripe Fruit	Number of Plants: Observed				Expected				Total	χ^2
	Days[a]	90-94	94-98	98-102	102-122	90-94	94-98	98-102	102-122		
1	Yes	11	22	9	1	1.6	5.4	19.0	17.0	43	
(T5-4-1 x	No	1	18	132	125	10.4	34.6	122.0	109.0	276	
'Saladmaster')	Total	12	40	141	126	12	40	141	126	319	145.50**
	Days[a]	86-90	90-94	94-98	98-114	86-90	90-94	94-98	98-114		
2	Yes	16	36	26	2	6.9	29.1	40.8	3.2	80	
(T5-4-1 x	No	14	91	152	12	23.1	97.9	137.2	10.8	269	
'Tiny Tim')	Total	30	127	178	14	30	127	178	14	349	25.48**
	Days[a]	78-94	94-98	98-102	102-106	78-94	94-98	98-102	102-106		
2R	Yes	12	10	7	0	4.3	10.3	8.2	6.3	29	
('Tiny Tim' x	No	4	29	24	24	11.7	28.7	22.8	17.7	81	
T5-4-1)	Total	16	39	31	24	16	39	31	24	110	28.34**
	Days[a]	82-90	90-94	94-98	98-102	82-90	90-94	94-98	98-102		
3	Yes	9	24	9	0	2.3	7.7	19.2	12.8	42	
(T5-4-1 x	No	2	13	84	62	8.7	29.3	73.8	49.2	161	
'Starshot')	Total	11	37	93	62	11	37	93	62	203	92.10**
	Days[a]	86-90	90-94	94-98	98-110	86-90	90-94	94-98	98-110		
3R	Yes	16	85	27	0	6.4	41.1	55.4	25.1	128	
('Starshot x	No	0	18	112	63	9.6	61.9	83.6	37.9	193	
T5-4-1)	Total	16	103	139	63	16	103	139	63	321	168.30**

**significant at .01 probability

[a]Number of days from planting to first ripe fruit

Table 7. Chi Square values for the relationship of parthenocarpic first ripe fruit to fruit weight in F_2 populations, 1977.

Cross	Parthenocarpic First Ripe Fruit	Number of Plants									
		Observed				Expected				Total	χ^2 [a]
	Grams[b]	20-40	40-50	50-60	60-80	20-40	40-50	50-60	60-80		
1	Yes	2	6	1	1	3.1	3.6	2.1	1.3	10	
T5-4-1 x	No	27	28	19	11	25.9	30.4	17.9	10.7	85	
'Saladmaster')	Total	29	34	20	12	29	34	20	12	95	2.95
	Grams[b]	10-20	20-30	30-40	40-50	10-20	20-30	30-40	40-50		
2	Yes	2	14	5	1	4.7	10.7	5.6	1.1	22	
T5-4-1 x	No	19	34	20	4	16.3	37.3	19.4	3.9	77	
'Tiny Tim')	Total	21	48	25	5	21	48	25	5	99	3.38
	Grams[b]	10-20	20-30	30-40	40-60	10-20	20-30	30-40	40-60		
2R	Yes	5	11	7	4	5.7	10.9	7.4	3.0	27	
(Tiny Tim' x	No	16	29	20	7	15.3	29.1	19.6	8.0	72	
T5-4-1)	Total	21	40	27	11	21	40	27	11	99	0.61
	Grams[b]	30-50	50-60	60-70	70-100	30-50	50-60	60-70	70-100		
3	Yes	4	5	2	6	3.3	5.1	2.5	6.1	17	
(T5-4-1 x	No	15	24	12	29	15.7	23.9	11.5	28.9	80	
'Starshot')	Total	19	29	14	35	19	29	14	35	97	0.27
	Grams[b]	40-60	60-70	70-80	80-100	40-60	60-70	70-80	80-100		
3R	Yes	9	8	6	18	12.7	8.2	7.0	13.1	41	
('Starshot' x	No	22	12	11	14	18.3	11.8	10.0	18.9	59	
T5-4-1)	Total	31	20	17	32	31	20	17	32	100	5.15

[a]All values non-significant at .05 probability [b]Average fruit weight in grams

Table 8. Statistical parameters for all populations of Cross 4 (T5 x 'Starshot'), based on individual plant data, 1979.[a]

Variable	Parameter	Transplants P_1	Transplants BC_1	Transplants F_1	Transplants F_2	Transplants F_2R	Transplants F_2&F_2R	Transplants BC_2	Transplants P_2	Direct-Seeded Plants P_1	Direct-Seeded Plants BC_1	Direct-Seeded Plants F_1	Direct-Seeded Plants F_2&F_2R	Direct-Seeded Plants BC_2	Direct-Seeded Plants P_2
First Flower[b]	Minimum	53	54	54	54	53	53	54	61	47	45	45	45	45	47
	Maximum	73	84	72	86	87	87	84	92	53	56	54	56	59	57
	Mean	57.60	60.68	60.29	65.36	64.12	64.74	66.82	75.35	49.55	50.31	48.52	48.92	50.03	51.04
	Std. Dev.	5.08	5.24	3.71	5.82	6.69	6.29	6.38	6.25	1.96	3.14	2.20	2.35	3.85	2.74
First Ripe Fruit[b]	Minimum	97	95	104	106	105	105	108	125	80	83	88	91	83	96
	Maximum	121	133	127	141	145	145	142	161	96	114	99	119	117	117
	Mean	105.55	111.44	111.83	119.90	118.54	119.22	122.27	133.32	86.06	90.79	94.95	95.58	98.31	109.00
	Std. Dev.	5.43	5.70	4.36	7.19	7.25	7.24	7.09	7.23	3.91	5.91	3.12	7.56	7.06	6.63
First Flower to First Ripe Fruit[c]	Minimum	38	35	37	40	38	38	42	49	32	38	43	36	38	49
	Maximum	65	78	61	79	85	85	82	100	43	58	51	72	58	67
	Mean	47.95	50.77	51.54	54.54	54.42	54.48	55.44	57.97	36.52	40.48	46.43	46.65	48.28	57.96
	Std. Dev.	6.28	5.91	3.31	5.85	6.29	6.57	6.34	7.75	2.76	3.09	2.10	7.69	6.87	5.64
Parthenocarpic First Ripe Fruit	Minimum	1	1	2	1	1	1	2	2	1	1	2	1	1	2
	Maximum	2	2	2	2	2	2	2	2	1	2	2	2	2	2
	Mean	1.23	1.78	2	1.02	1.86	1.83	2	2	1	1.10	2	1.61	1.86	2
	Std. Dev.	0.42	0.42	0	0.39	0.35	0.37	0	0	0	0.30	0	0.49	0.35	0
Reversions	Minimum	1	1	3	1	1	1	4	4	1	1	4	1	1	4
	Maximum	3	4	4	4	4	4	4	4	1	4	4	4	4	4
	Mean	1.73	2.72	3.99	3.19	3.41	3.30	4	4	1	1.29	4	2.84	3.57	4
	Std. Dev.	0.85	0.89	0.11	1.08	0.94	1.02	0	0	0	0.89	0	1.47	1.06	0
No. of Seedless Days	Minimum	4	0	0	0	0	0	0	0	20	0	0	0	0	0
	Maximum	62	54	7	55	47	55	0	0	30	34	0	33	27	0
	Mean	36.75	17.70	0.09	6.00	5.43	6.12	0	0	31.66	21.25	0	8.33	3.07	0
	Std. Dev.	13.18	12.01	0.80	10.06	9.27	9.69	0	0	4.03	9.75	0	11.09	7.74	0
First Ripe Fruit to Permanently Seedy[c]	Minimum	15	0	0	0	0	0	0	0	20	0	0	0	0	0
	Maximum	62	56	32	55	57	57	0	0	38	34	0	33	27	0
	Mean	45.28	28.69	0.42	10.99	9.20	10.10	0	0	31.56	21.15	0	8.48	3.07	0
	Std. Dev.	9.94	13.03	3.67	13.55	13.57	13.57	0	0	4.03	9.75	0	11.15	7.74	0

[a] Explanation of headings: P_1 = T5, P_2 = 'Starshot', $F_2 = P_1 \times P_2$, $F_2R = P_2 \times P_1$, $BC_1 = F_1 \times$ T5, $BC_2 = F_1 \times$ commercial parent. Parthenocarpic First Ripe Fruit: 1 = plus, 2 = minus. Reversions: 1 = all seedless, 2 = initially seedless, 1 reversion, 3 = initially seedy, 1 reversion, 4 = all seedy.

[b] Number of days from April 3 (transplants) or May 23 (direct-seeded plants)

[c] Number of days

Table 9. Statistical parameters for all populations of cross 5 (T5 x 'Saladmaster'), based on individual plant data, 1979.[a]

Variable	Parameter	Transplants P_1	Transplants BC_1	Transplants F_1	Transplants F_2	Transplants F_2R	Transplants F_2&F_2R	Transplants BC_2	Transplants P_2	Direct-Seeded Plants P_1	Direct-Seeded Plants BC_1	Direct-Seeded Plants F_1	Direct-Seeded Plants F_2&F_2R	Direct-Seeded Plants BC_2	Direct-Seeded Plants P_2
First Flower[b]	Minimum	53	53	57	54	54	54	59	61	47	47	47	45	47	42
	Maximum	73	87	03	95	95	95	93	83	53	58	56	57	61	56
	Mean	57.60	65.15	64.75	67.89	74.26	71.07	69.29	67.92	49.55	50.36	50.97	50.14	53.30	51.40
	Std. Dev.	5.08	8.71	4.35	7.83	8.46	8.74	8.44	4.37	1.96	2.90	2.66	2.96	3.16	3.29
First Ripe Fruit[b]	Minimum	97	100	110	99	107	99	113	125	80	81	95	87	84	114
	Maximum	121	131	128	146	148	148	150	146	96	99	117	116	117	117
	Mean	105.55	113.30	117.86	121.83	125.39	123.61	127.22	134.78	86.06	90.29	98.74	95.80	107.34	115.52
	Std. Dev.	5.43	6.45	3.88	8.01	7.14	7.78	8.23	5.62	3.91	4.55	4.70	5.03	8.00	1.05
First Flower to First Ripe Fruit[c]	Minimum	30	32	44	33	34	33	42	58	32	33	42	38	40	60
	Maximum	65	68	64	84	71	84	79	78	43	48	61	68	66	74
	Mean	47.95	48.16	53.11	53.94	51.13	52.54	57.94	66.86	36.52	39.93	47.77	45.66	54.05	64.12
	Std. Dev.	6.20	6.75	4.03	8.01	7.58	7.92	7.11	5.64	2.76	3.90	3.91	4.86	7.53	3.13
Parthenocarpic First Ripe Fruit	Minimum	1	1	2	1	1	1	1	2	1	1	2	1	1	2
	Maximum	2	2	2	2	2	2	2	2	1	2	2	2	2	2
	Mean	1.23	1.72	2	1.81	1.81	1.81	1.99	2	1	1.17	2	1.65	1.95	2
	Std. Dev.	0.42	0.45	0	0.39	0.39	0.39	0.08	0	0	1.38	0	0.48	0.22	0
Reversions	Minimum	1	1	4	1	1	1	1	4	1	1	4	1	1	4
	Maximum	3	4	4	4	4	4	4	4	1	4	4	4	4	4
	Mean	1.73	2.58	4	3.22	3.27	3.24	3.98	4	1	1.50	4	2.95	3.85	4
	Std. Dev.	0.85	1.04	0	1.08	1.41	1.11	0.25	0	0	1.13	0	1.44	0.65	0
No. of Seedless Days	Minimum	4	0	0	0	0	0	0	0	20	0	0	0	0	0
	Maximum	62	40	0	41	32	41	22	0	38	35	0	30	32	0
	Mean	36.75	15.43	0	6.68	4.80	5.75	0.15	0	31.66	21.31	0	6.04	1.07	0
	Std. Dev.	13.18	10.67	0	9.39	7.73	8.64	1.84	0	4.03	11.58	0	9.91	5.01	0
First Ripe Fruit to Permanently Seedy[c]	Minimum	15	0	0	0	0	0	0	0	20	0	0	0	0	0
	Maximum	62	52	0	50	36	50	22	0	38	35	0	30	32	0
	Mean	45.28	24.63	0	10.06	6.72	8.40	0.15	0	31.66	21.31	0	6.84	1.07	0
	Std. Dev.	9.94	13.06	0	12.74	9.91	11.52	1.04	0	4.03	11.58	0	9.91	5.01	0

[a]Explanation of headings: P_1 = T5, P_2 = 'Saladmaster', $F_2 = P_1 \times P_2$, $F_2R = P_2 \times P_1$, $BC_1 = F_1 \times$ T5, $BC_2 = F_1 \times$ commercial parent. Parthenocarpic First Ripe Fruit: 1 = plus, 2 = minus. Reversions: 1 = all seedless, 2 = initially seedless, 1 reversion, 3 = initially seedy, 1 reversion, 4 = all seedy.

[b]Number of days from April 3 (transplants) or May 23 (direct-seeded plants)

[c]Number of days

Table 10. Statistical parameters for all populations of cross 6 (T5 x 'Willamette'), based on individual plant data, 1979.[a]

Variable	Parameter	Transplants P_1	BC_1	F_1	F_2	F_2R	F_2 & F_2R	BC_2	P_2	Direct-Seeded Plants P_1	BC_1	F_1	F_2&F_2R	BC_2	P_2
First Flower[b]	Minimum	53	53	56	54	55	54	62	75	47	46	47	46	47	48
	Maximum	73	80	81	91	92	92	98	99	53	56	57	60	60	60
	Mean	57.60	62.17	66.95	70.10	70.95	70.52	77.33	86.58	49.55	49.74	50.83	50.32	53.05	54.21
	Std. Dev.	5.08	6.09	5.25	7.74	7.69	7.72	8.36	4.42	1.96	2.31	2.82	2.88	3.55	2.94
First Ripe Fruit[b]	Minimum	97	96	103	100	110	100	113	120	80	82	86	82	84	109
	Maximum	121	129	132	145	150	150	151	159	96	101	102	117	119	120
	Mean	105.55	111.27	118.54	123.01	122.96	122.98	131.85	145.80	86.06	88.64	97.05	97.29	105.21	116.68
	Std. Dev.	5.43	5.83	4.43	7.31	7.33	7.31	8.71	6.97	3.91	4.64	3.85	6.42	8.20	2.52
First Flower to First Ripe Fruit[c]	Minimum	38	30	41	40	32	32	39	30	32	32	39	33	30	57
	Maximum	65	70	65	82	72	82	70	68	43	53	53	70	66	68
	Mean	47.95	49.10	51.59	52.91	52.02	52.46	54.52	59.23	36.52	38.89	46.22	46.97	52.17	62.47
	Std. Dev.	6.28	7.39	4.41	7.07	6.64	6.86	5.54	6.68	2.76	4.63	3.13	5.75	8.20	3.10
Parthenocarpic First Ripe Fruit	Minimum	1	1	2	1	1	1	2	2	1	1	2	1	1	2
	Maximum	2	2	2	2	2	2	2	2	1	2	2	2	2	2
	Mean	1.23	1.52	2	1.84	1.89	1.86	2	2	1	1.09	2	1.61	1.98	2
	Std. Dev.	0.42	0.50	0	0.34	0.32	0.34	0	0	0	0.28	0	0.49	1.15	0
Reversions	Minimum	1	1	4	1	1	1	4	4	1	1	4	1	1	4
	Maximum	3	4	4	4	4	4	4	4	1	4	4	4	4	4
	Mean	1.73	2.13	4	3.21	3.45	3.35	4	4	1	1.26	4	2.84	3.93	4
	Std. Dev.	0.85	1.05	0	1.05	0.94	1.00	0	0	0	0.85	0	1.47	0.46	0
No. of Seedless Days	Minimum	4	0	0	0	0	0	0	0	20	0	0	0	0	0
	Maximum	62	65	0	37	42	42	0	0	38	39	0	34	15	0
	Mean	36.75	25.08	0	6.36	4.21	5.29	0	0	31.66	25.38	0	8.08	0.36	0
	Std. Dev.	13.18	15.67	0	9.01	7.79	8.48	0	0	4.03	10.01	0	10.84	2.31	0
First Ripe Fruit to Permanently Seedy[c]	Minimum	15	0	0	0	0	0	0	0	20	0	0	0	0	0
	Maximum	62	65	0	51	42	51	0	0	38	39	0	34	15	0
	Mean	45.28	31.53	0	10.72	6.86	8.79	0	0	31.66	25.38	0	8.08	0.36	0
	Std. Dev.	9.94	13.03	0	12.66	11.08	12.04	0	0	4.03	10.01	0	10.84	2.31	0
Fruit Weight (grams)	Minimum				18	18	18								
	Maximum				125	112	125								
	Mean				48.20	47.90	48.05								
	Std. Dev.				18.29	17.65	17.95								

[a]Explanation of headings: P_1 = T5, P_2 = 'Willamette', $F_2 = P_1 \times P_2$, $F_2R = P_2 \times P_1$, $BC_1 = F_1 \times$ T5, $BC_2 = F_1 \times$ commercial parent. Parthenocarpic First Ripe Fruit: 1 = plus, 2 = minus. Reversions: 1 = all seedless, 2 = initially seedless, 1 reversion, 3 = initially seedy, 1 reversion, 4 = all seedy.

[b]Number of days from April 3 (transplants) or May 23 (direct-seeded plants)

the F_1 mean is identical to, or almost identical to, the mean of the seedy parent (P_2) for all crosses and both planting methods; that is, all F_1 fruits were seedy, with the exception of 1 plant in cross 4 which may have been a seed mixture. The F_1 data thus indicate that the inheritance of parthenocarpy in T5 is recessive. This conclusion is supported further by the means of the backcrosses of the F_1s to the seedy parents (BC_2) for the same 2 variables, which are equal or very close to the mean of the seedy parent for all crosses and both planting methods. These backcross populations showed more variation than the F_1, particularly in the direct-seeded plants. The F_2 means for these 2 variaables are biased toward the seedy parent, again indicating dominance of seediness. The data for the quantitative measurements of parthenocarpy, total number of seedless days and number of days from first ripe fruit to permanently seedy, support these conclusions.

The frequency of parthenocarpic first ripe fruit varied from an average of 16% in the transplants to an average of 38% in the direct-seeded plants for the F_2 populations of crosses 4, 5, and 6 (Tables 11-13). However, when the plus or minus data for the first ripe fruit are combined with the reversions variable, the transplants and direct-seeded plants behaved very much the same, making the total percentage of F_2 plants that

Table 11. Frequency distributions of parthenocarpic first ripe fruit for cross 4 (T5 x 'Starshot'), 1979.[a]

Population		Transplants: Parthenocarpic First Ripe Fruit yes	no	Reversions yes 1	2	3	no 4	Total yes	no	X^2	Direct Seeded Plants: Parthenocarpic First Ripe Fruit yes	no	Reversions yes 1	2	3	no 4	Total yes	no	X^2
P_1	#	31	9	21	10	9	0	40	0		29	0	29	0	0	0	29	0	
	%	77	23	53	25	22	0	100	0		100	0	100	0	0	0	100	0	
BC_1	#	33	116	26	7	98	18	131	18	12.52**[c]	47	5	47	0	0	5	47	5	5.77*[c]
	%	22	78	17	5	66	12	88	12		90	10	90	0	0	10	90	10	
F_1	#	0	76	0	0	1	75	1	75		0	21	0	0	0	21	0	21	
	%	0	100	0	0	1	99	1	99		0	100	0	0	0	100	0	100	
F_2	#	36	161	32	4	56	105	92	105										
	%	18	82	16	2	28	53	47	53	0.58[d]									
F_2R	#	27	169	10	9	44	125	71	125										
	%	14	86	9	5	22	64	36	64	4.21*[d]									
F_2 & F_2R	#	63	330	50	13	100	230	163	230		65	103	65	0	0	103	65	103	
	%	16	84	13	3	25	59	41	59	0.73[d]	39	61	39	0	0	61	39	61	1.55[d]
BC_2	#	0	147	0	0	8	147	0	147		10	60	10	0	0	60	10	60	
	%	0	100	0	0	0	100	0	100		14	86	14	0	0	86	14	86	
P_2	#	0	37	0	0	0	37	0	37		0	27	0	0	0	27	0	27	
	%	0	100	0	0	0	100	0	100		0	100	0	0	0	100	0	100	

[a]Explanation of symbols: P_1 = T5, P_2 = 'Starshot', $F_2 = P_1 \times P_2$, $F_2R = P_2 \times P_1$, $BC_1 = F_1 \times$ T5, $BC_2 = F_2 \times$ commercial parent

[b]Reversions: 1 = all seedless, 2 = initially seedless, 1 reversion, 3 = initially seedy, 1 reversion, 4 = all seedy

[c]Tested against a 1 seedy:3 seedless ratio

[d]Tested against a 9 seedy:7 seedless ratio

*significant at .05 probability

**significant at .01 probability

Table 12. Frequency distributions of parthenocarpic first ripe fruit for cross 5 (T5 x 'Saladmaster'), 1979.[a]

Population		Transplants									Direct Seeded Plants								
		Parthenocarpic First Ripe Fruit		Reversions				Total		χ^2	Parthenocarpic First Ripe Fruit		Reversions				Total		χ^2
		yes	no	yes			no	yes	no		yes	no	yes			no	yes	no	
				1	2	3	4						1	2	3	4			
P_1	#	31	9	21	10	9	0	40	0		29	0	29	0	0	0	29	0	
	%	77	23	53	25	22	0	100	0		100	0	100	0	0	0	100	0	
BC_1	#	23	58	22	1	47	11	70	11		35	7	35	0	0	7	35	7	
	%	28	72	27	1	50	14	86	14	4.99*[c]	83	17	83	0	0	17	83	17	1.14[c]
F_1	#	0	120	0	0	0	120	0	120		0	39	0	0	0	39	0	39	
	%	0	100	0	0	0	100	0	100		0	100	0	0	0	100	0	100	
F_2	#	37	162	31	6	50	112	87	112										
	%	19	81	16	3	25	56	44	56	0.003[d]									
F_2R	#	37	161	36	1	35	126	72	126										
	%	19	31	18	1	18	64	36	64	4.09*[d]									
F_2 & F_2R	#	74	323	67	7	85	238	159	238		72	129	72	0	0	129	72	129	
	%	19	01	17	2	21	60	40	60	2.04[d]	36	64	36	0	0	64	36	64	4.80*[d]
BC_2	#	1	142	1	0	0	142	1	142		3	58	3	0	0	58	3	50	
	%	1	99	1	0	0	99	1	99		5	95	5	0	0	95	5	95	
P_2	#	0	36	0	0	0	36	0	36		0	25	0	0	0	25	0	25	
	%	0	100	0	0	0	100	0	100		0	100	0	0	0	100	0	100	

[a] Explanation of symbols: P_1 = T5, P_2 = 'Saladmaster', $F_2 = P_1 \times P_2$, $F_2R = P_2 \times P_1$, $BC_1 = F_1 \times$ T5, $BC_2 = F_1 \times$ commercial parent

[b] Reversions: 1 = all seedless, 2 = initially seedless, 1 reversion, 3 = initially seedy, 1 reversion, 4 = all seedy

[c] Tested against a 1 seedy:3 seedless ratio

[d] Tested against a 9 seedy:7 seedless ratio

*significant at .05 probability

**significant at .01 probability

Table 13. Frequency distributions of parthenocarpic first ripe fruit for cross 6 (T5 x 'Willamette'), 1979.[a]

Population		Transplants: Parthenocarpic First Ripe Fruit yes	no	Reversions yes 1	2	3	no 4	Total yes	no	χ^2	Direct Seeded Plants: Parthenocarpic First Ripe Fruit yes	no	Reversions yes 1	2	3	no 4	Total yes	no	χ^2
P_1	#	31	9	21	10	9	0	40	0		29	0	29	0	0	0	29	0	
	%	77	23	53	25	22	0	100	0		100	0	100	0	0	0	100	0	
BC_1	#	48	51	43	5	46	5	94	5	20.0**[c]	43	4	43	0	0	4	43	4	5.90*[c]
	%	48	52	43	5	46	5	94	5		91	9	91	0	0	9	90	10	
F_1	#	0	79	0	0	0	79	0	79		1	40	1	0	0	40	1	40	
	%	0	100	0	0	0	100	0	100		2	98	2	0	0	98	2	98	
F_2	#	32	166	30	2	62	104	94	104										
	%	16	04	15	1	31	53	47	53	0.90[d]									
F_2R	#	22	176	20	2	39	137	61	137										
	%	11	89	10	1	20	69	31	69	12.93**[d]									
F_2 & F_2R	#	54	342	50	4	101	241	155	241		74	117	74	0	0	117	74	117	
	%	14	86	13	1	26	61	39	61	3.24[d]	39	61	39	0	0	61	39	61	1.76[d]
BC_2	#	0	117	0	0	0	117	0	117		0	42	0	0	0	42	0	42	
	%	0	100	0	0	0	100	0	100		0	100	0	0	0	100	0	100	
P_2	#	0	40	0	0	0	40	0	40		0	19	0	0	0	19	0	19	
	%	0	100	0	0	0	100	0	100		0	100	0	0	0	100	0	100	

[a]Explanation of symbols: P_1 = T5, P_2 = 'Willamette', $F_2 = P_1 \times P_2$, $F_2R = P_2 \times P_1$, $BC_1 = F_1 \times$ T5, $BC_2 = F_1 \times$ commercial percent

[b]Reversions: 1 = all seedless, 2 = initially seedless, 1 reversion, 3 = initially seedy, 1 reversion, 4 = all seedy

[c]Tested against a 1 seedy: 3 seedless ratio

[d]Tested against a 9 seedy:7 seedless ratio

*significant at .05 probability

**significant at .01 probability

were seedless at some time during the growing season about 40% for both transplants and direct-seeded plants (Tables 11-13). This also agrees with the data for cross 3R ('Starshot' x T-5-4-1) in the 1977 study and is considered to represent maximum expression of parthenocarpy for F_2 populations of crosses with T5 observed under the conditions of this study. As was mentioned for cross 3R in the 1977 study, this most closely fits a 9 seedy:7 seedless genetic ratio, indicating duplicate recessive genes (Tables 11-13). When tested separately, however, the F_2 population (parthenocarpic x normal) fits a 9:7 ratio, while the F_2R population (normal x parthenocarpic) does not. This difference between the F_2 and F_2R populations is consistent for all 3 crosses and agrees with the Chi square tests for reciprocal differences (Table 3) which showed significant differences between F_2 and F_2R populations for the reversions category for all 3 crosses. Since F_2R involved the normal parent as female, these results may indicate a degree of cytoplasmic inheritance or influence. When the plus or minus data for the first ripe fruit and the reversions data are combined in considering the backcrosses, transplants and direct-seeded plants again behaved very much the same, the backcross to the seedy parent (BC_2) showing an average of 3% parthenocarpic plants and the backcross to the seedless parent (BC_1) showing an average of 89% parthenocarpic plants.

The ratio of seedy to seedless plants in BC_1 for all crosses tends to fit a 1 seedy:3 seedless ratio, the genetic ratio expected for duplicate recessive genes in a backcross to the recessive parent. In the cases where Chi square values indicate a poor fit, there was more seedlessness than expected, suggesting possible modifiers. BC_2 was essentially 100% seedy, as expected, in most cases. There was some seedlessness in 2 of the crosses in direct-seeded plants, again suggesting the possible presence of modifiers.

The same kinds of results can be seen for the quantitative measurement of parthenocarpy, total number of seedless days. The significant F values for populations in the analysis of variance (Table 14) indicate that in all 3 crosses there are significant differences among means for populations. Duncan's Multiple Range Test was used to test each population mean for differences from all other population means (Table 15). As was the case with the qualitative measurements of parthenocarpy, the F_1 and BC_2 means for total number of seedless days are not significantly different from the mean of the seedy parent (P_2). This is true for all 3 crosses, indicating again that the inheritance of parthenocarpy in T5 is recessive. As with the qualitative measurements of parthenocarpy, the F_2 means are biased toward P_2 (normal parent). The BC_1 means are higher than the

Table 14. Analysis of Variance for total number of seedless days, 1979.

Cross	Source of Variation[a]	df	ms	Observed F	Required F 5%	1%
4 (T5 x 'Starshot')	population	7	1101.0	155.14**	2.22	3.05
	method	1	10.2	1.44	4.05	7.21
	replications	3	8.6	1.21	2.81	4.24
	error	45	7.10			
5 (T5 x 'Saladmaster')	population	7	1092.4	169.10**	2.22	3.05
	method	1	6.6	1.03	4.05	7.21
	replications	3	7.2	1.12	2.81	4.24
	error	45	6.46			
6 (T5 x 'Willamette')	population	7	1312.1	192.25**	2.22	3.05
	method	1	0.7	0.10	4.05	7.21
	replications	3	3.9	0.57	2.81	4.24
	error	45	6.83			

[a]Method = transplanted or direct-seeded

*significant at .05 probability

**significant at .01 probability

Table 15. Population means for total number of seedless days, 1979.[a]

Cross	Population[b]	Population Mean [c]	
	P_2	0	a
	F_1	0	ab
4 (T5 x 'Starshot')	BC_2	1.29	abc
	F_2R	6.06	d
	F_2+F_2R	7.05	de
	F_2	7.36	def
	BC_1	18.85	g
	P_1	34.11	h
	P_2	0	a
	F_1	0	ab
5 (T5 x 'Saladmaster')	BC_2	0.60	abc
	F_2R	6.24	d
	F_2xF_2R	6.60	de
	F_2	6.90	def
	BC_1	17.65	g
	P_1	34.11	h
	P_2	0	a
	F_1	0.13	ab
6 (T5 x 'Willamette')	BC_2	0.21	abc
	F_2R	4.83	d
	F_2xF_2R	6.31	de
	F_2	7.79	def
	BC_1	25.11	g
	P_1	34.11	h

[a]Transplants and direct-seeded plants are combined for each cross.

[b]Explanation of symbols: P_1 = T5, P_2 = commercial parent, F_2 = P_1xp_2, F_2R = P_2xP_1, BC_1=F_1xT5, BC_2=F_1 x commercial parent.

[c]Duncan's Multiple Range Test; means followed by a common letter are not significantly different at .05 probability.

F_2 means, but lower than those of P_1.

The frequency distributions of the variable total number of seedless days are shown in Figures 1 and 2 for transplants and direct-seeded plants, respectively. The P_2, F_1 and BC_2 populations in most cases did not vary from 0, but for the purposes of these graphs are indicated by a bar in the 0 to 10 column. For the transplants, the expression of P_1 showed a range of 10 to 60 days, with a concentration at 40 to 50 days. The expression of BC_1 showed a similar range, but with a concentration at about 20 days, approximately the midpoint value. The expression of the F_2 covered a range of from 0 to 50 days but was highly skewed toward P_2 with about 80% of the population seedy. In the direct-seeded plants the ranges were smaller in most cases; otherwise the results were similar.

Another way of expressing these data is with a line graph of the populations (Figure 3), where the X-axis is a genetic proportion between the seedless parent (P_1) on the left and the seedy parent (P_2) on the right. The Y-axis is the total number of seedless days. Figure 3 clearly shows the dominance of seediness, with the F_1, F_2, BC_1, and BC_2 means all skewed toward P_2. If inheritance were additive, these graphs would show a straight line, with the F_1 and F_2 means intermediate between P_1 and P_2.

Relationships were tested between parthenocarpy

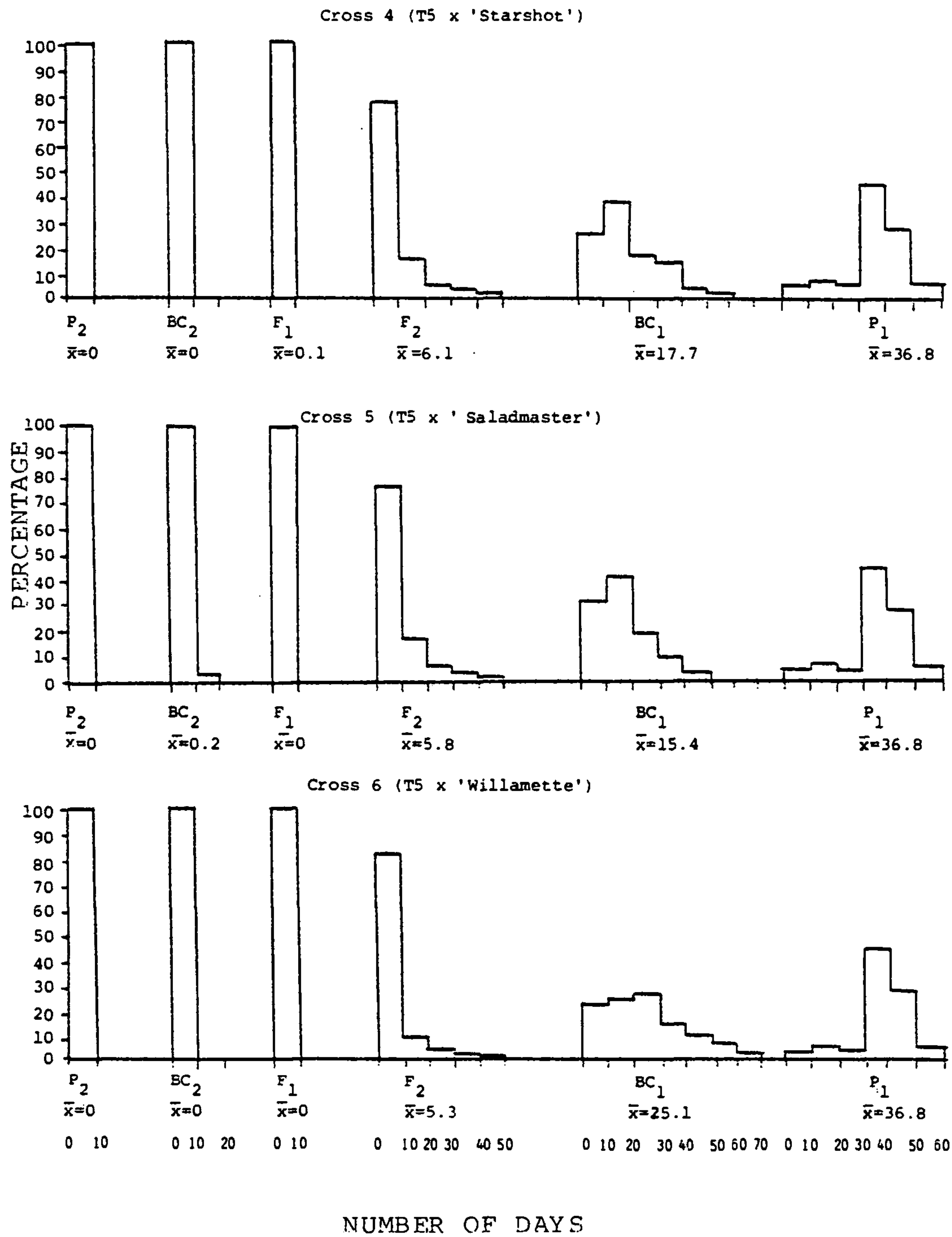

Figure 1. Distribution in percent population across total number of seedless days, transplants, 1979.

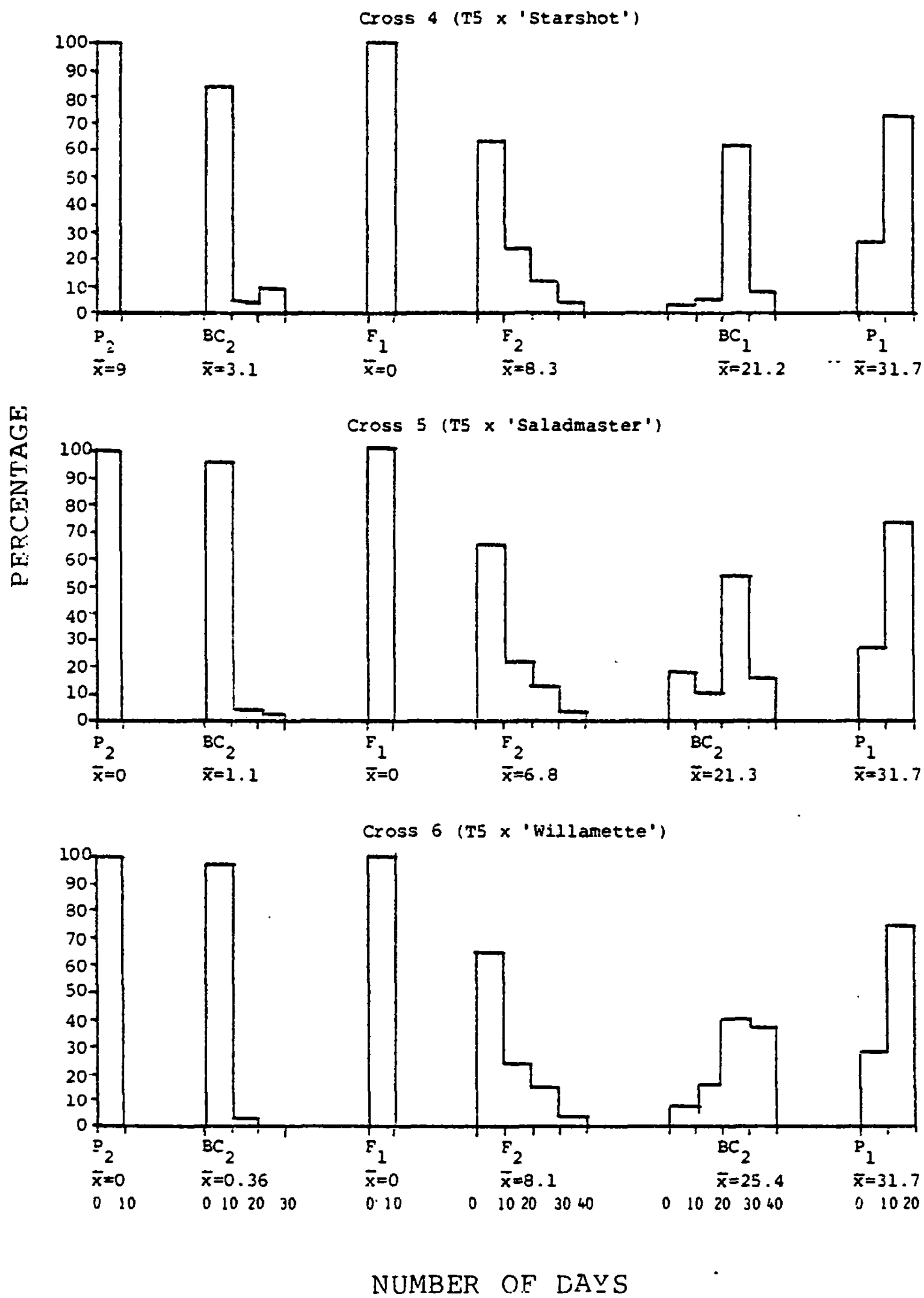

Figure 2. Distribution in percent population across total number of seedless days, direct-seeded plants, 1979.

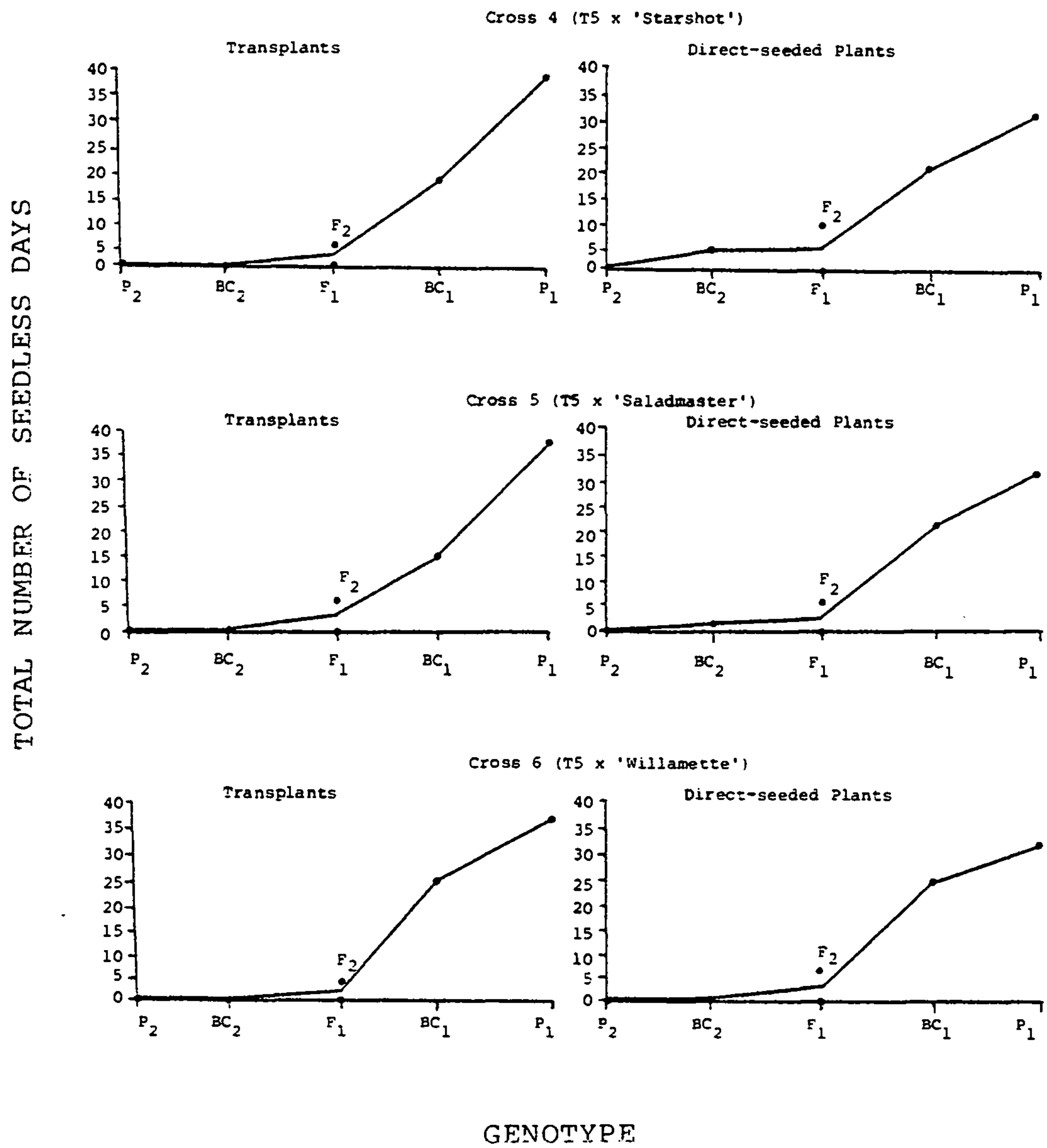

Figure 3. Variation in total number of seedless days with population means as a function of genotype, 1979.

and the characteristics first flowering date, first ripe fruit date, number of days from first flower to first ripe fruit, and fruit weight. (Relationships between parthenocarpy and fruit weight were tested for cross 6 only, the only new cross in the 1979 study.) Chi square (χ^2) tests (Tables 16-19) were used to determine relationships for the qualitative measurement of parthenocarpy (the plus or minus reading on the first ripe fruit) and correlation coefficients (Table 20) were used for the quantitative measurement (total number of seedless days). Combined F_2 and F_2R data were used in Tables 16-20.

Results of the Chi square tests for the 1979 data are not as clear as for the 1977 data; however, the same trends can be seen. In most cases no association is shown between parthenocarpy and date of first flower. There are 2 exceptions, cross 5, transplants, and cross 6, direct-seeded plants. It should be noted, however, that in the case of cross 5, transplants, the association is not as expected, that is, there are more seedless tomatoes than expected at both the early and late ends of the scale, and more seedy tomatoes than expected in the middle of the scale. The large Chi square value, therefore, cannot be taken to mean that seedless tomatoes flowered either earlier or later than seedy tomatoes. This is not the case, however, with cross 6, direct-seeded plants. In this case a large

Table 16. Chi square values for the relationship of parthenocarpic first ripe fruit to first flower date in F_2 populations, 1979.

Cross	Planting Method[a]	Parthenocarpic First Ripe Fruit	Number of Plants									
			Observed				Expected				Total	χ^2
4 (T5 x 'Starshot')	TP	Days[b]	50-60	60-70	70-80	80-90	50-60	60-70	70-80	80-90		
		Yes	7	39	15	2	11.4	40.1	9.8	1.8	63	
		No	64	211	46	9	59.6	209.9	51.2	9.2	330	
		Total	71	250	61	11	71	250	61	11	393	5.40
	DS	Days[b]	45-50	50-55	55-60		45-50	50-55	55-60			
		Yes	35	29	1		39.1	24.8	1.7		65	
		No	66	35	2		61.9	39.2	1.8		103	
		Total	101	64	3		101	64	3		168	1.91
5 (T5 x 'Saladmaster')	TP	Days[b]	50-60	60-70	70-80	80-100	50-60	60-70	70-80	80-100		
		Yes	6	29	10	29	3.7	35.0	20.1	15.1	74	
		No	14	159	98	52	16.3	153.0	87.9	65.9	323	
		Total	20	188	108	81	20	188	108	81	397	24.98**
	DS	Days[b]	45-50	50-55	55-60		45-50	50-55	55-60			
		Yes	27	34	11		21.1	40.5	10.4		72	
		No	32	79	18		37.9	72.5	18.6		129	
		Total	59	113	29		59	113	29		201	4.21
6 (T5 x 'Willamette)	TP	Days[b]	50-60	60-70	70-80	80-100	50-60	60-70	70-80	80-100		
		Yes	2	26	18	8	2.2	26.5	16.6	8.7	54	
		No	14	168	104	56	13.8	167.5	105.4	55.3	342	
		Total	16	194	122	64	16	194	122	64	396	0.23
	DS	Days[b]	45-50	50-55	55-60		45-50	50-55	55-60			
		Yes	54	14	6		42.2	27.1	4.6		74	
		No	55	56	6		66.8	42.9	7.4		117	
		Total	109	70	12		109	70	12		191	15.94**

[a]TP = transplants, DS = direct-seeded plants.

[b]Number of days from planting to first flower.

**significant at .01 probability

Table 17. Chi square values for the relationship of parthenocarpic first ripe fruit to first ripe fruit date in F_2 populations, 1979.

Cross	Planting Method	Parthenocarpic First Ripe Fruit	Number of Plants: Observed				Expected				Total	χ^2
		Days[b]	100-110	110-120	120-130	130-150	100-110	110-120	120-130	130-150		
		Yes	6	28	20	9	2.7	31.7	23.2	5.3	63	
	TP	No	11	170	125	24	14.3	166.3	121.8	27.7	330	
		Total	17	198	145	33	17	198	145	33	393	8.85*
4 (T5 x 'Starshot')		Days[b]	80-90	90-100	100-110	110120	80-90	90-100	100-110	110-120		
		Yes	10	50	5	0	5.0	43.7	15.1	1.2	65	
	DS	No	3	63	34	3	8.0	69.3	23.9	1.8	103	
		Total	13	113	39	3	13	113	39	3	168	22.63**
		Days[b]	90-110	110-120	120-130	130-150	90-110	110-120	120-130	130-150		
		Yes	5	18	27	24	1.7	26.5	23.7	22.2	74	
	TP	No	4	124	100	95	7.3	115.5	103.3	96.8	323	
5 (T5 x 'Saladmaster')		Total	9	142	127	119	9	142	127	119	397	12.8**
		Days[b]	80-90	90-100	100-110	110-120	80-90	90-100	100-110	110-120		
		Yes	19	47	6	0	8.2	42.3	19.0	2.5	72	
	DS	No	4	71	47	7	148	75.7	4.5	4.5	129	
		Total	23	118	53	7	23	118	53	7	201	40.47**
		Days[b]	100-110	110-120	120-130	130-150	100-110	110-120	120-130	130-150		
		Yes	4	27	17	6	1.1	26.7	20.7	5.5	54	
	TP	No	4	169	135	34	6.9	169.3	131.3	34.5	342	
		Total	8	196	152	40	8	196	152	40	396	9.82*
6 (T5 x 'Willamette')		Days[b]	80-90	90-100	100-110	110-120	80-90	90-100	100-110	110-120		
		Yes	26	35	13	0	12.0	31.8	26.7	3.5	74	
	DS	No	5	47	56	9	19.0	50.2	42.3	5.5	117	
		Total	31	82	69	9	31	82	69	9	191	44.35**

[a]TP = transplants, DS = direct-seeded plants
[b]Number of days from planting to first ripe fruit
*significant at .05 probability
**significant at .01 probability

Table 18. Chi square values for the relationship of parthenocarpic first ripe fruit to number of days from first flower date to first ripe fruit date in F_2 populations, 1979.

Cross	Planting Method	Parthenocarpic First Ripe Fruit	Number of Plants									
			Observed				Expected				Total	χ^2
		Days[b]	30-40	40-50	50-60	60-90	30-40	40-50	50-60	60-90		
		Yes	6	33	21	3	1.0	27.7	28.2	5.3	63	
	TP	No	5	140	155	30	9.2	145.3	147.8	27.7	330	
		Total	11	173	176	33	11	173	176	33	393	16.69**
4 (T5 x 'Starshot')		Days[b]	30-40	40-50	50-60	60-80	30-40	40-50	50-60	60-80		
		Yes	14	49	1	1	6.2	49.5	6.2	3.1	65	
	DS	No	2	79	15	7	9.8	78.5	9.8	4.9	103	
		Total	16	120	16	8	16	128	16	8	168	25.49**
		Days[b]	30-40	40-50	50-60	60-90	30-40	40-50	50-60	60-90	74	
		Yes	9	33	16	16	3.4	22.7	36.2	11.7	323	
	TP	No	9	89	178	47	14.6	99.3	157.8	51.3	397	33.07**
		Total	18	122	194	63	18	122	194	63		
5 (T5 x 'Saladmaster)		Days[b]	30-40	40-50	50-60	60-70	30-40	40-50	50-60	60-70		
		Yes	9	61	2	0	4.7	56.2	8.6	2.5	72	
	DS	No	4	96	22	7	0.3	100.8	15.4	4.5	129	
		Total	13	157	24	7	13	157	24	7	201	18.73**
		Days[b]	30-40	40-50	50-60	60-90	30-40	40-50	50-60	60-90		
		Yes	3	31	17	3	0.5	24.7	24.0	4.8	54	
	TP	No	1	150	159	32	3.5	156.3	152.0	30.2	342	
		Total	4	101	176	35	4	181	176	35	396	17.79**
6 (T5 x 'Willamette)		Days[b]	30-40	40-50	50-60	60-70	30-40	40-50	50-60	60-70		
		Yes	32	39	3	0	14.7	49.6	7.7	1.9	74	
	DS	No	6	89	17	5	23.3	70.4	12.3	3.1	117	
		Total	38	128	20	5	38	128	20	5	191	44.71**

[a]TP = transplants, DS = direct-seeded plants
[b]Number of days from first flower to first ripe fruit
**significant at .01 probability

Table 19. Chi square values for the relationship of parthenocarpic first ripe fruit to fruit weight in F_2 populations, transplants, 1979.

Cross	Partheno- First Ripe Fruit	Number of Plants									
		Observed				Expected				Total	χ^2
	Grams[a]	10-30	30-50	50-70	70-130	10-30	30-50	50-70	70-130		
6	Yes	4	20	13	17	5.6	27.4	14.7	6.3	54	
(T5 x	No	37	181	95	29	35.4	173.6	93.3	39.7	342	
'Willamette')	Total	41	201	108	46	41	201	108	46	396	24.32**

[a]Average fruit weight in grams

**significant at .01 probability

Table 20. Correlation of number of seedless days with maturity and fruit weight in F_2 populations, 1979.

Cross	Planting Method[a]	n	Correlated Variable[b]	Correlation Coefficient
4 (T5 x 'Starshot')	TP	393	First Flower	.008
			First Ripe Fruit	-.122*
			First Flower to First Ripe Fruit	-.142**
	DS	168	First Flower	.023
			First Ripe Fruit	-.449**
			First Flower to First Ripe Fruit	-.448**
5 (T5 x 'Saladmaster')	TP	397	First Flower	-.023
			First Ripe Fruit	-.218**
			First Flower to First Ripe Fruit	-.189**
	DS	201	First Flower	-.112
			First Ripe Fruit	-.470**
			First Flower to First Ripe Fruit	-.430**
6 (T5 x 'Willamette')	TP	396	First Flower	-.162**
			First Ripe Fruit	-.287**
			First Flower to First Ripe Fruit	-.134**
			Fruit Weight	.159**
	DS	191	First Flower	-.269**
			First Ripe Fruit	-.568**
			First Flower to First Ripe Fruit	-.499**

[a]TP = transplants, DS = direct-seeded plants

[b]Number of days

*significant at .05 probability

**significant at .01 probability

Chi square value indicates that the seedless plants did flower significantly earlier than the seedy plants. It may be that under certain environmental conditions and in crosses with a relatively late flowering plant such as 'Willamette', the length of time to flowering becomes important.

Significant Chi square values indicate an association between parthenocarpy and date of first ripe fruit, stronger in the direct-seeded plants than in the transplants. As in the data from 1977, parthenocarpic fruit ripened significantly earlier than seedy fruit. A strong association is also indicated between parthenocarpy and the number of days from first flower to first ripe fruit in all 3 crosses and for both planting methods. In every case the ripening period from flowering to ripe fruit was shorter for the plants bearing parthenocarpic fruit than for the plants bearing normal fruit. These data suggest that plants bearing parthenocarpic fruit are earlier, not because they flower earlier, but because the length of the ripening period is shorter. It may be that the physiological condition of parthenocarpy causes earlier ripening. It may also be that plants that do not set parthenocarpic fruit will not set fruit at all for a period of time in the spring when temperatures are cool.

For cross 6, the only cross for which average fruit data were taken in 1979, a relationship is indicated between parthenocarpy and fruit weight, parthenocarpic fruit being significantly larger on the average than normal fruit. This is contrary to the results in the 1977 data where no relationship was found between parthenocarpy and an average fruit weight in the 3 crosses listed, and was due to the high number of large and very misshapen seedless fruit appearing in this cross. In general, these studies indicate there is no relationship between parthenocarpy and fruit size as measured by fruit weight.

The correlation coefficients (Table 20) between the variable total number of seedless days and the 3 expressions of maturity support the conclusions drawn from the Chi square tests. Significant correlation coefficients indicate a relationship between first ripe fruit date and total number of seedless days for all crosses and both planting methods. The correlations were negative; that is, as the number of seedless days (parthenocarpy) increased, the number of days to first ripe fruit decreased. A negative relationship is also shown between number of days from first flower to first ripe fruit and total number of seedless days for all crosses and both planting methods. The similarity in results for the two variables, first ripe fruit date and number of days from first flower to first ripe fruit, was seen in both the correlation coefficients and the Chi square tests (Tables 17 and 18). It should be noted that these two variables may be expected to be similar because variation in first flower date in the F_2 populations of all crosses was not large (Tables 8-10).

For cross 6, a small but significant positive correlation is shown between average fruit weight and total number of seedless days; as parthenocarpy increased, the average fruit size also increased. For crosses 4 and 5, both planting methods, no association is indicated between total number of seedless days and first flower date, but significant correlation coefficients indicate a relationship is present between these two variables in cross 6. The relationship is negative; the greater the degree of parthenocarpy, the shorter the time to first flower. Generally, the correlations for transplants were small, though usually significant at .01 probability, but correlations for direct-seeded plants were substantial.

1980 Study

The data from the parents and F_2 populations of a cross between T5 and 'Severianin', a parthenocarpic tomato cultivar from Russia, are summarized in Table 21.

Reciprocal F_2 populations were not significantly different and were combined. T5 ripened an average

Table 21. Statistical parameters for parents and F_2 populations based on individual plant data, 1980.

Variable	Parameter	Population T5	Population 'Severianin'	Population F_2
First[a] Ripe Fruit	Minimum	80	104	85
	Maximum	96	121	122
	Mean	90.12	110.51	96.62
	Std. Dev.			6.89
Seedless Days	Minimum			0
	Maximum			80
	Mean			13.34
	Std. Dev.			13.45
Fruit Weight (grams)	Minimum			17
	Maximum			169
	Mean			64.98
	Std. Dev.			30.39
Parthenocarpic First Ripe Fruit	No. Fruit Examined	28	23	362
	% Partheno-carpic	100	100	66
	Chi square			9.52** [b]

[a]Number of days from May 19 planting date.

[b]Tested against 37 seedless: 27 seedy genetic ratio.

**significant at .01 probability

of 20 days earlier than 'Severianin'; the F_2 covered the range of ripening dates of both parents, with an average fruit ripe fruit date about in the middle. Both T5 and 'Severianin' had 100% parthenocarpic first ripe fruit. Sixty-six percent of the first ripe fruit were parthenocarpic in the F_2 population; 238 plants out of a total of 362 direct-seeded plants.

Previous work indicates that parthenocarpy in 'Severianin' is due to a single recessive gene (24). If parthenocarpy in T5 were caused by the same gene, the F_1 and F_2 populations of a cross between the 2 would be expected to have only parthenocarpic plants. Since this was not the case, it can be concluded that parthenocarpy in T5 results from a different gene or genes than in 'Severianin'.

Data from the 1977 study, and especially the 1979 study, suggest that parthenocarpy in T5 may be due to 2 recessive genes. The ratio of parthenocarpic to normal plants in the F_2 of the cross between T5 and 'Severianin' was therefore tested for goodness of fit to a 37 seedless:27 seedy genetic ratio, using Chi square tests (Table 21). This is the expected genetic ratio for 3 recessive genes, where T5 carries 2 which are different from a third carried by 'Severianin'. Although there are more seedless than seedy first ripe fruit in the F_2 of this cross, the significant Chi square value (9.52) suggests the data do not fit this ratio. This cannot be explained by lack of expression of the parthenocarpic character, since there were more seedless fruit than expected. The interaction of modifiers for parthenocarpy from the 2 parents might explain the increased seedlessness, and support the previously proposed hypothesis of 2 major recessive genes for parthenocarpy in T5.

GENERAL DISCUSSION

F_1, F_2 and backcross data from 4 tomato crosses, both transplants and direct-seeded plants, tested for 2 growing seasons, indicate that the inheritance of parthenocarpy in T5 is recessive, as has been previously reported in the literature for other parthenocarpic tomato cultivars. When environmental conditions promoted maximum expression of parthenocarpy, however, the ratio of seedy to seedless fruit did not fit a 3:1 ratio, indicating parthenocarpy in T5 is not due to a single gene, as has been reported for material from Italy (31) and for 'Severianin', a parthenocarpic Russian cultivar (24). Chi square tests indicating a good fit to a 9 seedy:7 seedless ratio suggest that parthenocarpy in T5 may be due to 2 recessive genes, a similar finding to that reported for the German cultivar '75/59' (24).

Data from a cross between 'Severainin' and T5 tend to support this hypothesis, although these data do not closely fit the expected ratio of 37 seedless:27 seedy for 3 recessive genes, 2 from T5 and 1 from 'Severianin'. The interaction of modifiers for parthenocarpy from the parents may explain the increased expression of parthenocarpy in this cross. It is clear from the F_2 data of this cross that different genes control parthenocarpy in T5 and 'Severianin'. However, it is not possible to determine if parthenocarpy in T5 is due to different genes than in the Italian and German parthenocarpic material, since no crosses were made with this material. Therefore, no gene designation is proposed in this study.

Both preliminary and complete data for all 4 crosses and both planting methods indicate an association between parthenocarpy and earliness as measured by the number of days to first ripe fruit. This agrees with other reports in the literature of early maturing parthenocarpic cultivars (6, 31). This earlier ripening in T5 crosses seems to result from a shorter period of time required from first flower to first ripe fruit, and not from earlier flowering, in most cases. No association was found between parthenocarpy and fruit size as measured by average fruit weight except in one case, where several large, misshapen fruit skewed the data.

SUMMARY AND CONCLUSIONS

F_1, F_2 and backcross data clearly indicate that the inheritance of parthenocarpy in T5 is recessive. F_2 data fit a 9 seedy:7 seedless ratio, suggesting duplicate recessive genes.

F_2 data from a cross with 'Severianin', an unrelated parthenocarpic cultivar, show that the inheritance of parthenocarpy in T5 is due to a different gene than in 'Severianin'. These data also tend to support the hypothesis of 2 genes for parthenocarpy in T5, with a possible interaction of modifiers for parthenocarpy from both parents.

An association exists between parthenocarpy and earliness, and results from a shorter period of time required from first flower to first ripe fruit, rather than from earlier flowering, in most cases. In general, no association exists between parthenocarpy and fruit size.

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