A STUDY OF THE HYBRID VIGOR OF REDSKIN TOMATO IN RECIPROCAL CROSSES

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INTRODUCTION

The fact that the offspring of reciprocal crosses usually have been identical, indicates that most hereditary characters are equally contributed by the male and female gametes. This is in agreement with a generally accepted genetic theory. However, cases do arise where reciprocal crosses produce unlike results for certain characters, and these appear to be inherited almost entirely through the female parent by means of the cytoplasmic contents of the egg cell.

Tomato reciprocal crosses have repeatedly been shown to be alike, indicating that there was no detectable material or cytoplasmic influence. The subject has recently been re-opened by the finding of significant differences in the yield of reciprocal hybrids involving the Redskin variety. This fact takes on greater importance in the light of present day trends toward the utilization of the heterosis of F_1 hybrids, which have demonstrated superior fruit yields and earliness when compared to selfed lines of tomatoes.

In this study the Redskin variety has been used in four reciprocal crosses, and the differences in hybrid vigor of the F_1 as manifested by earliness and yield, size and weight of fruit, have been analysed statistically.

REVIEW OF LITERATURE

A number of reports comparing reciprocal hybrids of the tomato, which have shown no differences, have been published since 1900. Hedrick and Booth (11) in 1907 reported that "seedlings from the direct and the reciprocal cross were similar in all respects" when Livingstone Stone and Dwarf Aristocrat were crossed. Craig (5) who worked with Hedrick stated that reciprocal crosses gave practically the same results. Price and Drinkard (16) from an extensive study of the inheritance in the F_1 of such fruit characteristics as color, shape and locule number, concluded that "the reciprocal crosses gave similar results in the hybrid offspring."

Halstead (9) made a study of the relative values of the two directions of the cross in reciprocal breeding and used the contrasting varieties Dandy Dwarf and Yellow Cherry. He concluded that the fruit characters - weight and size - of the seed parent were approached in both crosses. Driver (7) reported a case where reciprocal hybrids seemed to differ, where "The fruit quality of Kondine x Market Favorite was good, but that from the reciprocal was not so satisfactory. Here maturity was equal to the earlier parent in one cross but intermediate in the reciprocal."

In another reciprocal cross he states, "only one was earlier than both parents." Meyer and Peacock (15) found a strain of Marglobe which when used as a male parent for the production of F_1 hybrids, was somewhat superior in early yield and total yield than when used as a female parent.

Barrons and Lucas (4) from the results of three years study reported that it was immaterial whether a variety was used as the male or female for the production of F_1 hybrid tomato seed. Continuing these studies Barrons (3) found a new greenhouse hybrid-- Michigan State Forcing x Coopers Special-- no different in yield than its reciprocal. Larson and Currence (14) tested seven reciprocals involving the varieties Earliana, Red River and Marglobe, and "found that they did not differ significantly from one another in any character." Currence, Larson and Virta (6) made the observation that "those instances where differences have been statistically tested show no significance between reciprocal crosses.

Recently Walkof (19) found that F_1 hybrids with Redskin as the female parent produced significantly more ripe fruit than their reciprocals. He also found the cross Bounty x Redskin to be later ripening than its reciprocal.

In addition to the above studies of the tomato, interesting related information concerning reciprocal crosses and F_1 hybrids has been reported for other crops.

Ashley (1) when studying the nature of hybrid vigor in corn, found F_1 seed heavier than either parent. Further, that the hybrid embryo was larger and heavier than that of the parents and so germinated with an initial advantage which was retained throughout the life cycle. In a later article (2) he reported the embryo weight of the seed of two parents to differ significantly as well as the embryo weights of the reciprocal crosses, even though the reciprocal crosses had the same genetical constitution. He presented this as evidence that the difference was due to a maternal effect during the development of the embryo before the seed entered upon its resting period.

Kakizaki (13) investigated hybrid vigor in egg plants and reported that the F_1 seed in most crosses was heavier due to the immediate effect of cross pollination, than the selfed seed of the mother parent.

Hutchins (12) found that "there was no difference in the behavior of reciprocal crosses insofar as yield per plant of the F_1 generations was concerned," in cucumber.

MATERIALS AND METHOD

Parental varieties - Redskin, Earliana, Farthest North, Harkness and Early Chatham - were selected on the basis of contrasting and similar characteristics, namely plant habit, maturity, fruit size and fruit shape. These have been listed in Table A of the appendix.

Reciprocal crosses were made in the greenhouse of the Dominion Experimental Farm, Indian Head, Saskatchewan, during the spring of 1946, using the variety Redskin, as either the male or female parent in each cross. A single plant of each variety, with the exception of Redskin, was used as the pollen and seed parent in the crosses made. In the case of Redskin, four plants were deemed necessary to ensure sufficient seed. The resulting eight reciprocal F_1 hybrids were assigned at random the planting numbers listed in Table B of the appendix. Duplicate samples of 25 seeds, from each cross, were weighed in milligrams; these data are given in Table C of the appendix.

The hybrid seed was sown in the greenhouse on April 25, 1947. Plants, produced and handled according to standard practice, were set out in the field on June 11, 1947. The planting plan adopted was an 8 x 8 latin square as described by Goulden (8), and is given in Table D of the appendix. Plots consisted of four plants spaced 4 feet by 4 feet.

Fruits were harvested twice a week beginning August 16. A general red coloration was used as the indication of harvest maturity. Eight subsequent harvests were made before September 15, when frost terminated the season. The number of fruits of each harvest and their weights in grams were recorded. Fruits of each harvest were classified as to quality into grades of No. 1, Marketable, and Culls.

Fruit weight in grams was used as an index of fruit size. Fruit sizes herein reported were computed by averaging the weights of individual fruits obtained from two prime pickings. Polar and equatorial measurements to tenths of an inch were also made, and the average fruit shape index, E/P, was calculated by dividing the equatorial dimension of each fruit by its polar dimension.

The term "total yield" constituted the grand total of all fruits harvested from a plot, while the term "marketable" was used to designate the total of no. 1 and marketable fruits, when the number of no. 1 fruits proved to be few due to the limited season. Similarly, "total early yield" is used to refer to the grand total of fruits harvested in the first two weeks, and "early marketable yield" indicates the total marketable fruits produced in the same period.

For the purpose of analysis plot totals were converted to pounds. The records were analyzed for early yield, total yield, fruit shape, fruit size and seed weight, to determine whether the differences between reciprocals were significant. Analysis of variance was first applied to the data to ascertain the need of further analysis, and also to find the standard error value. As significant F values were obtained for the treatments in all cases, the mean values of the respective pairs of reciprocal hybrids were calculated to determine whether their differences were significant. Procedures as outlined by Goulden (8) and Hayes and Immer (10), for the analysis of variance of a latin square design, and for the calculation of the differences required for significance at the 5% and 1% levels, were followed in this study.

Seed weight data of reciprocal hybrids were analyzed as paired variates. The method as outlined by Goulden (8) for testing the significance of small samples was followed, and the difference necessary for significance at the 5% level has been given. Total yields were used, as a source of fruit size data rather than marketable yields, on the assumption that if unmarketable fruits were excluded, a bias would be introduced in favor of hybrids producing a large number of undesirable fruits in addition to a few superior marketable fruits.

RESULTS AND DISCUSSION

1. Total Yields of the F_1 Reciprocal Crosses.

The analysis of variance computed in Table 1, showed treatments, which are the eight reciprocal hybrids, to be highly significant, and indicated that significant differences occurred between the mean yields of the hybrids. It indicated also that significant differences in yield occurred between the various rows and columns of the plantation due to environmental effects. Total yields of the eight reciprocal F_1 hybrids in pounds, have been listed by plots in Table D of the appendix.

Table 1. Analysis of Variance of Total Yields in Pounds

Source	S.S.	D.F.	Variance	F.	S.D.
Rows	190.6811	7	27.2402	3.54^{xx}	
Columns	247.0806	7	35.2972	4.59^{xx}	
Treatments	1179.9808	7	168.5687	21.92^{xx}	
Error	322.9917	42	7.6903		2.7731
Total	1940.7342	63			

^{xx}Significant at the 1% level

Table II presents the total yields along with mean yields and the differences between reciprocal hybrids. Definite differences are exhibited between the means of certain reciprocals. In crosses involving Earliana, where Redskin was the female parent, yields were significantly

greater than when Redskin was the pollen parent. The reverse was true for reciprocal hybrids of Redskin and Early Chatham. When Redskin was the male or pollen parent, the yields were greater than ~~with~~ the reciprocal to the highly significant level. No significant difference was apparent between the mean total yields of reciprocal crosses of Redskin and Harkness. Reciprocals of Redskin and Farthest North showed highly significant differences in favor of the hybrid with Redskin as the pollen parent.

Table II. Total Yields, Means and Mean Differences of the F_1 Reciprocal Hybrids in Pounds

F_1 Hybrid	Total Yield	Mean	Diff.
Redskin x Farthest North	67.25	8.41	
Farthest North x Redskin	121.77	15.22	6.81
Redskin x Earliana	154.65	19.33	
Earliana x Redskin	124.49	15.56	3.77
Redskin x Harkness	71.19	8.90	
Harkness x Redskin	69.20	8.65	0.25
Redskin x Early Chatham	112.86	14.11	
Early Chatham x Redskin	155.74	19.47	5.36

Significant Difference at the 5% level = 2.80 lbs.
Significant Difference at the 1% level = 3.74 lbs.

II. Total Marketable Yields of the F_1 Reciprocal Crosses.

Total marketable yields have been summarized in Table F of the appendix. These were analyzed by analysis of variance and the mean differences were tested for significance.

The analysis of variance is given in Table III, and the mean differences in Table IV.

Table III. Analysis of Variance of Total Marketable Yields in Pounds

Source	S.S.	D.F.	Variance	F.	S.D.
Rows	142.2436	7	20.3205	2.75^{x}	
Columns	168.8544	7	24.1221	3.27^{xx}	
Treatments	830.5039	7	118.6434	16.09^{xx}	
Error	309.7844	42	7.3758		2.7158
Total	1451.3863	63			

^{xx}Significant at the 1% level
^{x}Significant at the 5% level

Table IV. The Total Marketable Yields, Means and Mean Differences of F_1 Reciprocal Hybrids in Pounds

F_1 Hybrid	Marketable Yields	Mean	Diff.
Redskin x Farthest North . . .	63.36	7.92	
Farthest North x Redskin . . .	107.65	13.46	5.54
Redskin x Earliana	135.67	16.96	
Earliana x Redskin	110.00	13.75	3.21
Redskin x Harkness	68.16	8.52	
Harkness x Redskin	67.90	8.49	0.03
Redskin x Early Chatham . . .	106.32	13.29	
Early Chatham x Redskin . . .	142.27	17.78	4.49

Significant Difference at the 5% level = 2.74 lbs.
Significant Difference at the 1% level = 3.66 lbs.

Analysis of variance of total marketable yields similar to that of total yields, showed highly significant F-value differences between treatments. It is evident from this that certain reciprocal hybrids were definitely different in mean marketable yields.

F_1 hybrids of Redskin and Farthest North gave mean marketable yield, which exceeded that of the reciprocal by a highly significant amount, when Redskin was the male parent of the cross. The same was true with the F_1 hybrids of Redskin and Early Chatham, for significantly superior yields were obtained where Redskin was the pollen parent. Redskin and Harkness reciprocals showed no significant differences. In the above six hybrids, the results for marketable yields were similar to those obtained for total yields; that is apparent in Table IV.

However, the difference between mean yields of Redskin and Earliana reciprocals, which was highly significant for total yields, was found to be significant only at the five percent level for marketable yields. This indicated that harvests of the F_1 Redskin x Earliana contained more cull fruit (fasciated and small) than the reciprocal. By actual count, the number of cull fruits for the former was 56 and for the latter 39.

III. Total Early Yields of Reciprocal F_1 Hybrids

Fruit yields harvested the first two weeks were used to evaluate the earliness of maturity exhibited by the F_1 hybrids. A summary of the total early yields has been given in Table G of the appendix.

The analysis of variance of total early yields, given in Table V, shows a highly significant F value for treatments, indicating that significant differences occurred between the mean yields of the hybrids.

Table V. The Analysis of Variance of Total Early Yields

Source	S.S.	D.F.	Variance	F.	S.D.
Rows	10.6246	7	1.5178	1.58	
Columns	14.5656	7	2.0808	2.16	
Treatments	72.5381	7	10.3626	10.78^{xx}	
Error	40.3867	42	0.9616		0.9806
Total	221.4400	63			

^{xx}Significant at the 1% level

The mean early yields of reciprocal crosses were tested for significant differences in Table VI. Two F_1 hybrids, Farthest North x Redskin, and Early Chatham x Redskin, proved to be earlier beyond the highly significant level than their respective reciprocals. In both cases the superior F_1 of the reciprocals had the Redskin variety as its pollen parent. The remaining reciprocals showed no significant differences.

Table VI. The Total Early Yields and Mean Differences of the F_1 Reciprocal Hybrids in Pounds

F_1 Hybrid	Total Early Yields	Mean	Diff.
Redskin x Farthest North	7.73	0.97	
Farthest North x Redskin	38.33	4.79	3.82
Redskin x Earliana	42.98	5.37	
Earliana x Redskin	35.46	4.43	0.94
Redskin x Harkness	17.73	2.22	
Harkness x Redskin	17.84	2.23	0.01
Redskin x Early Chatham	32.35	4.04	
Early Chatham x Redskin	43.47	5.43	1.39

Significant Difference at the 5% level = 0.99 pounds.
Significant Difference at the 1% level = 1.32 pounds.

IV. Analysis of Marketable Early Yields

These data are given by plots in Table H of the appendix. From the analysis of variance given in Table VII, a highly significant variation due to treatments is shown.

The marketable early yields in pounds of the eight hybrids are listed in Table VIII. As with the total early yields, two F_1 hybrids, Farthest North x Redskin, and Early Chatham x Redskin, exhibited significantly earlier maturity than their respective reciprocals. Again, in both, Redskin was the pollen parent.

Table VII. Analysis of Variance of Marketable Early Yields

Source	S.S.	D.F.	Variance	F.	S.D.
Rows	11.1711	7	1.5959	1.59	
Columns	12.9743	7	1.8535	1.85	
Treatments	147.0337	7	21.0048	20.97^{xx}	
Error	42.0748	42	1.0018		1.0009
Total	213.2539	63			

^{xx}Significant at the 1% level

Table VIII. The Marketable Early Yields and Mean Yield Differences from F_1 Reciprocal Hybrids in Pounds

F_1 Hybrid	Marketable Early Yields	Mean	Diff.
Redskin x Farthest North	7.48	0.93	
Farthest North x Redskin	37.92	4.74	3.71
Redskin x Earliana	41.80	5.22	
Earliana x Redskin	35.08	4.38	0.84
Redskin x Harkness	17.73	2.22	
Harkness x Redskin	17.84	2.23	0.01
Redskin x Early Chatham	31.16	3.89	
Early Chatham x Redskin	42.29	5.29	1.40

Significant Difference at the 5% level = 1.01 pounds.
Significant Difference at the 1% level = 1.35 pounds.

V. Analysis of Fruit Size

Fruit size data have been listed by plots in Table J of the appendix.

The significance exhibited by treatments in the analysis of variance of fruit size, as given in Table IX, indicates that there were differences between the various hybrids.

Table IX. The Analysis of Variance of Average Fruit Size in Grams. Averages made from the Total Yields of Two Prime Harvests

Source	S.S.	D.F.	Variance	F.	S.D.
Rows	1620	7	231	1.58	
Columns	2372	7	339	2.32	
Treatments	24233	7	3462	23.71^{xx}	
Error	6131	42	146		12.0821
Total	34356	63			

^{xx}Significant at the 1% level

From Table X, where the differences between the mean fruit size of the eight hybrids have been listed, it is apparent that only the crosses between Farthest North and Redskin exhibited a significant difference between reciprocals. No other pair of reciprocal crosses showed any difference over and above that due solely to random sampling.

The difference in fruit size, as portrayed by the average weight of the respective fruit of Redskin and Farthest North reciprocal hybrids, clarified the differences

found for yield data between these hybrids. It was apparent that the Redskin x Farthest North hybrid, which produced significantly larger fruit than the Farthest North x Redskin reciprocal hybrid, was inferior in yielding ability. This would indicate that the yielding ability as measured by weight was inversely proportional to the fruit size (average fruit weight) for this pair of reciprocal hybrids. Further, it was noticed that the larger fruit, of the Redskin and Farthest North hybrids, was produced by the F_1 hybrid having Redskin as its seed parent.

Table X. Average Fruit Size in Grams of the Eight F_1 Hybrids

F_1 Hybrid	Fruit Size	Difference
Redskin x Farthest North	106.4	
Farthest North x Redskin	78.8	37.6
Redskin x Earliana	131.6	
Earliana x Redskin	142.1	10.5
Redskin x Harkness	106.1	
Harkness x Redskin	116.0	9.9
Redskin x Early Chatham	91.5	
Early Chatham x Redskin	97.4	5.9

Significant Difference at the 5% level = 12.2 grams.
Significant Difference at the 1% level = 16.3 grams.

VI. Analysis of Fruit Shape-Index

Measurements were made of marketable fruits from each harvest. However, it was deemed advisable to use only the

results of two prime harvests for analysis of shape, in order to attain the greatest possible uniformity of this variable factor. A fruit shape-index value of 1.00 indicates a perfectly round fruit, while values greater than this indicate flattened fruits. Data, regarding fruit shape-index, have been listed in Table K of the appendix, and the values given for each respective plot.

The analysis of variance of fruit shape in Table XI gave significant F values for rows, columns and treatments, which indicates a high degree of variability of fruit shape within the plantation due to environmental conditions alone.

Table XI. Analysis of Variance of Fruit Shape

Source	S.S.	D.F.	Variance	F.	S.D.
Rows	0.0192	7	0.0027	3.86^{xx}	
Columns	0.0127	7	0.0018	2.57^{x}	
Treatments	0.3854	7	0.0551	78.71^{xx}	
Error	0.0296	42	0.0007		0.0266
Total	0.4469	63			

^{xx}Significant at the 1% level
^{x}Significant at the 5% level

The mean fruit-shape indices of the reciprocal hybrids are listed in Table XII. Reciprocal hybrids of Redskin and Early Chatham exhibited significantly different fruit shapes, as interpreted by shape-index. Redskin as the pollen parent produced fruit definitely flatter than those of the reciprocal. The reciprocal hybrids of Redskin and Farthest North

showed very large differences of fruit shape. The fruit of the F_1 hybrid, having Redskin as its seed parent, tended to exhibit the typical fruit shape of the Redskin variety; while that of the reciprocal hybrid approached the roundish fruit shape of Farthest North, its seed parent.

The remaining hybrids showed no significant differences between reciprocals as to fruit shape.

Table XII. Mean Fruit Shape-Index of the Eight Reciprocal Hybrids

F_1 Hybrid	Shape Index	Difference
Redskin x Farthest North	1.231	
Farthest North x Redskin	0.955	0.276
Redskin x Earliana	1.052	
Earliana x Redskin	1.040	0.012
Redskin x Harkness	0.995	
Harkness x Redskin	1.020	0.025
Redskin x Early Chatham	1.009	
Early Chatham x Redskin	1.075	0.056

Significant difference at the 5% level = 0.027
Significant difference at the 1% level = 0.036

VII. Analysis of Seed Weights.

Two samples of 25 seeds each, from the eight lots of hybrid seed, were weighed and recorded in milligrams prior to sowing. These weights have been listed in Table D of the appendix.

Table XIII. Mean Seed Weights in Milligrams of Each of the Four Hybrids and Their Respective Reciprocals

Hybrid Parents	With Redskin as the		
	Seed Parent	Pollen Parent	Diff.
Earliana	89.7	87.5	2.2
Harkness	114.5	93.7	20.8
Early Chatham	93.0	80.5	12.5
Farthest North	87.5	110.0	22.5
Totals	384.7	298.5	13.0
Means	96.2	92.9	3.3

Difference Necessary Between Means of the Two Groups for significance at the 5% level = 29.85 mg.

Table XIV. Mean Seed Weights in Milligrams of Three Hybrids and Their Respective Reciprocals

Hybrid Parents	With Redskin as the		
	Seed Parent	Pollen Parent	Diff.
Earliana	89.7	87.5	2.2
Harkness	114.5	93.7	20.8
Early Chatham	93.0	80.5	12.5
Totals	297.2	261.7	35.5
Means	99.1	87.2	11.9

Difference Necessary Between Means of the Two Groups for significance at the 5% level = 23.13 mg.

The mean seed weights of all eight hybrids were analyzed and are presented in Table XIII. No significant differences between seed weights of reciprocal hybrids were evident.

This indicates that no significant mean difference of seed weights occurred between F_1 hybrids having Redskin as their seed parent and those having Redskin as the pollen parent.

Data related to Redskin and Farthest North hybrids, which appeared to be of a reverse nature to the remaining hybrids, have been omitted in a similar analysis presented in Table XIV. Still no significant differences of seed weight were found to exist between the six remaining lots of F_1 hybrid seed. This analysis indicates that the differences, in seed weights of reciprocal hybrids, were no greater than that expected due to random sampling.

VIII. Discussion of Results for Reciprocal Hybrids.

A summary of the significant and non-significant mean differences found between the four pairs of reciprocal hybrids, comparing characteristics of yields and fruit type, has been listed in Table XV. A similar summary with the actual means will be found in Table L of the appendix.

1. Redskin-Farthest North Hybrids. Analysis showed consistent significant superiority of total yield, early yield and marketable yield in favor of the Farthest North x Redskin F_1 hybrid. The significantly greater yield of this hybrid over its reciprocal was 33% for total marketable yield and 63% for early marketable yield.

Table XV. A Summary of the Significant and Non-Significant Differences Between Four Pairs of Reciprocal Hybrids

Hybrids	Characteristics					
	Total Yield	Total Mark. Yield	Total Early Yield	Early Mark. Yield	Fruit Size	Fruit Shape
R. x F.N.* . . .					xx	xx
F.N. x R. . . .	xx	xx	xx	xx		
R. x E.	xx	x				
E. x R.						
R. x H.						
H. x R.						
R. x E.C. . . .						
E.C. x R. . . .	xx	xx	xx	xx		xx

x Significantly different at the 5% level
xx Significantly different at the 1% level

* Abbreviations:- R. - Redskin, F.N. - Farthest North, E. - Earliana, H. - Harkness, E.C. - Early Chatham. Mark. - Marketable.

The Redskin x Farthest North hybrid exhibited superiority of fruit size and portrayed a flatter fruit shape than that of the above reciprocal hybrid.

Fruit size, of the Farthest North x Redskin hybrid (a medium fruited parent crossed with a small fruited parent), proved to be intermediate with a tendency towards that of the smaller parent. This was in agreement with the general finding reported by MacArthur (16). This F_1 hybrid produced a round fruit shape as indicated by its shape index

of 0.95, which proved to be almost typical of the Farthest North parent; however, in appearance the fruit exhibited slightly the pointed character of its Redskin parent, which seems to have been obscured by the shape-index value. Based on the shape-index, the round character of Farthest North would appear to be dominant, but in appearance the pointed character of Redskin was dominant. Lindstrom (15) suggested that obovate fruit shape, which would describe Redskin, seemed to be dominant over round. It would appear that the fruit-shape-index as used in this study lacked sufficient accuracy for an analysis of fruit shape involving the pointed character.

Seed weight, of this pair of reciprocal hybrids, demonstrated no significant difference. It appears likely that that may be due to the limited data available, as Ashley (1) reported significance with corn hybrids as did Kakizaki (13) with egg plant hybrids.

With the exception of the crosses between Redskin and Farthest North, no visual differences were apparent between plants of the respective reciprocal hybrids. Plants of the Redskin x Farthest North F_1 hybrid were semi-upright in habit, while those of the Farthest North x Redskin F_1 hybrid were prostrate. It would appear that the semi-upright habit exhibited by the former hybrid was linked in some manner to the fruit shape character. However, any further explanation

is beyond the scope of the data available.

2. Redskin-Earliana Hybrids. Reciprocal hybrids involving Redskin and Earliana exhibited greater total yield significant at the 1% level and greater total marketable yield for the Redskin x Earliana hybrid. Data for early yield, fruit size and fruit shape produced no significant difference between reciprocals.

Results, which showed the F_1 hybrid having Redskin as its seed parent superior in yield, supported the findings reported by Walkof (19). An explanation for this phenomenon was not available from the data collected concerning fruit size, fruit shape and seed weight. It must be concluded, therefore, that insufficient information has been collected, or that some form of maternal or cytoplasmic influence was involved. Further it appears that genes or maternal influences responsible for total yield are apparently not involved with the character for early maturity. This fact has been previously observed by Larson and Currence (14).

3. Redskin-Harkness Hybrids. The tomato varieties, Redskin and Harkness, failed to demonstrate measurable differences in their reciprocal hybrids for the yield, fruit type and seed characters studied.

The performance of these reciprocal F_1 tomato hybrids supported the generally accepted genetical theory that reciprocal hybrids have identical genetical constitutions, and show this similarity throughout their life cycle.

A prominent characteristic of this pair of reciprocals was that almost their entire crop of fruit proved to be of marketable quality; whereas in all other reciprocals a portion of the fruit crop tended to be of unmarketable quality due to small size. Late maturity, resulting in extremely small mature yields, was the prime demerit of these hybrids.

4. Redskin-Early Chatham Hybrids. Redskin and Early Chatham reciprocal hybrids provided data to prove that the hybrid with Early Chatham as its seed parent, was superior to its reciprocal with respect to all the yield characteristics studied, and in addition portrayed a significantly flatter fruit shape. These reciprocals, however, failed to exhibit a measurable difference for fruit size or seed weight.

Significant differences demonstrated by the Early Chatham x Redskin hybrid, suggest that a greater number of favorable gene combinations occurred, when Early Chatham was the seed parent than when Redskin was the seed parent. This would not be possible if the reciprocal hybrids had identical

genetic constitutions.

Support for the equality theory of reciprocal hybrids appeared in the form of similar fruit sizes for both hybrids. Lindstrom (15) and other investigators have reported fruit size to be the result of the action of a number of genes, some of which were linked with fruit shape factors. These hybrids failed to indicate such linkage of fruit size and fruit shape factors. Further, the genes for the fruit size appeared to have little or no influence upon yield, as measured by weight.

The hybrid with Early Chatham as the seed parent exhibited a fruit shape distinctly different from the reciprocal even when this character was determined by a relatively crude method. This suggested that the factors, which influenced fruit shape, may also be involved with the yield characters. Still to have a sound genetical basis these factors would also be expected to produce a similar yield and shape response in the reciprocal hybrid. Such was not the case.

Even the knowledge that the Early Chatham variety was derived from a cross involving Redskin as one parent, fails to supply a factorial basis to explain the differences found between their reciprocal hybrids.

Consequently, the differences found between the

reciprocal hybrids of Early Chatham and Redskin would appear to result from some maternal or cytoplasmic influence derived from the Early Chatham parent. Apparently the maternal influence, which affected yield, was also involved in the modification of the shape factors inherited. Information relating to the genetical constitution of these varieties, and the inheritance of certain characters such as fruit shape and seed weight, appear to be essential prerequisites that are not now available.

SUMMARY

Four reciprocal pairs of tomato hybrids, using the Redskin variety with Farthest North, Harkness, Earliana and Early Chatham, were studied to determine differences between the reciprocals in a latin square design. Records were made of total yield, total marketable yield, total early yield, and early marketable yield, in grams, which have been converted to pounds for analysis. Fruit size in grams was obtained by averaging the individual fruit weights from the total yields of two prime harvests, and the fruit shape index, E/P, was determined by measuring the equatorial and polar dimensions of the marketable fruit from the same harvests. Duplicate samples of the hybrid seed were weighed and recorded, but provided insufficient data to be of value.

Analysis of variance has been applied to the respective data, and the mean differences necessary for significance between pairs of reciprocal hybrids have been calculated.

The F_1 hybrid, Farthest North x Redskin, consistently showed superior yields to that of its reciprocal hybrid, and produced round fruit similar to the Farthest North parent, but they were of intermediate size. The Redskin x Farthest North reciprocal hybrid exhibited superiority in fruit size, and yielded flattened fruit. In addition, two distinctly different plant types were apparent for these reciprocal

hybrids, indicating that the above differences were due to characters not given consideration in this study.

Reciprocal hybrids of Redskin and Harkness failed to demonstrate any measurable differences in the yield, fruit, and seed characteristics studied. These hybrids proved late maturing, but produced the highest percentage of marketable fruit.

Hybrids of Earliana and Redskin exhibited a greater total yield and a significantly greater total marketable yield, when Redskin was the seed parent.

Early Chatham and Redskin reciprocals provided data which showed the Early Chatham x Redskin hybrid to be superior for all four yield characteristics, and to have a significantly flatter fruit shape. No measurable differences were found for fruit size or seed weight between these reciprocal hybrids.

Four reciprocal hybrids exhibited differences for which no genetical factorial basis appears to apply. It has been concluded that the differences found between reciprocals in favor of Redskin as the seed parent in one case and Early Chatham in the other, would appear to be the result of some maternal or cytoplasmic influence. Final solution of the problem requires information concerning the genetical constitution and inheritance of Redskin and Early Chatham characters which appear to be related to the study.

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APPENDIX

Table "A" Characteristics of the Five Tomato Varieties Used as Parents

Variety	Character			
	Habit	Earliness	Fruit Shape	Fruit Size
Redskin	Det.	Early	Obovate Pointed	Medium
Early Chatham . .	Det.	Early	Obovate Blunt	Medium
Earliana	Indet.	Midseason	Flat	Large
Farthest North .	Det.	Very Early	Round	Small
Harkness	Indet.	Midseason	Flat	Medium

Abbreviations: Det. = determinate; Indet. = Indeterminate

Table "B". Key to Planting Numbers

1. Farthest North x Redskin
2. Redskin x Harkness
3. Earliana x Redskin
4. Redskin x Earliana
5. Redskin x Farthest North
6. Early Chatham x Redskin
7. Redskin x Early Chatham
8. Harkness x Redskin

Table "C" Weight of Two Samples of 25 Seeds from Each of the F_1 Crosses, in Milligrams

F_1 Cross	Seed Sample Wt.		Av.
Farthest North x Redskin . .	116.0	104.0	110.0 mg.
Redskin x Farthest North . .	92.0	83.0	87.5
Earliana x Redskin	93.0	82.0	87.5
Redskin x Earliana	92.0	87.5	89.7
Harkness x Redskin	92.0	94.5	93.7
Redskin x Harkness	115.0	114.0	114.5
Early Chatham x Redskin . .	87.0	74.0	80.5
Redskin x Early Chatham . .	94.0	92.0	93.0

Table "D" Planting Plan of the Experiment an 8 x 8 Latin Square

Columns	I	II	III	IV	V	VI	VII	VIII
Rows								
A.	1	2	4	3	5	8	7	6
B.	2	5	6	7	1	3	4	8
C.	5	4	2	1	8	7	6	3
D.	6	3	7	8	2	4	1	5
E.	4	8	5	2	6	1	3	7
F.	3	6	8	4	7	2	5	1
G.	7	1	3	6	4	5	8	2
H.	8	7	1	5	3	6	2	4

TABLE "E" Total Yields in Pounds by Plots

Columns	1	2	3	4	5	6	7	8	Row Totals
Rows									
A	11.25	6.07	12.55	14.69	5.29	10.21	13.61	15.89	89.56
B	6.02	9.36	17.88	12.23	12.85	18.63	20.93	7.62	105.52
C	10.90	22.64	9.69	15.83	8.08	14.79	18.79	21.41	122.13
D	22.00	13.69	14.41	9.32	10.46	30.75	20.30	16.35	137.28
E	17.31	5.49	5.56	7.30	19.42	18.73	22.91	14.83	111.55
F	11.38	17.67	9.24	18.26	14.27	10.11	6.91	20.57	108.41
G	17.58	10.45	9.50	19.99	15.92	8.48	13.41	10.64	105.97
H	5.83	11.14	11.79	4.40	12.28	24.10	10.90	16.29	96.73
Column Totals	102.27	96.51	90.62	102.02	98.57	135.80	127.76	123.60	877.15

TABLE "F" Total Marketable Yields in Pounds by Plots

Columns	1	2	3	4	5	6	7	8	Row Totals
Rows									
A	9.69	6.07	12.55	12.88	4.88	9.69	12.38	14.17	82.31
B	6.02	9.36	16.43	12.11	10.80	15.76	17.06	7.62	95.16
C	10.90	21.13	9.22	14.57	7.93	13.64	17.80	19.06	114.25
D	20.26	12.66	12.92	9.32	8.68	26.71	19.31	14.59	125.45
E	14.04	5.39	5.56	7.08	17.81	15.39	17.23	14.11	96.61
F	11.38	16.72	8.71	16.41	13.42	10.11	6.59	18.12	101.46
G	16.55	8.86	9.50	18.24	14.43	7.08	13.41	10.15	98.22
H	5.83	10.19	10.91	4.40	11.53	20.84	10.83	13.34	87.87
Column Totals	94.67	90.38	86.80	95.01	89.48	119.22	114.61	111.16	801.33

Table "G" Total Early Yields in Pounds by Plots

Columns	1	2	3	4	5	6	7	8	Row Totals
Rows									
A	5.10	1.75	4.17	4.89	0.32	2.28	4.82	4.48	27.81
B	1.72	2.40	5.37	2.75	3.11	5.38	5.48	2.80	29.01
C	0.94	7.11	3.20	5.51	2.27	3.68	6.64	7.18	36.53
D	5.33	4.06	4.81	2.42	1.32	6.48	5.11	2.29	31.82
E	3.98	0.56	1.59	1.65	4.60	4.38	3.61	5.08	25.45
F	3.93	5.43	3.18	5.31	3.08	1.52	0.19	7.42	30.06
G	4.70	4.11	2.94	5.59	5.45	0.00	3.73	2.35	28.87
H	0.60	3.43	3.59	0.00	3.47	6.03	4.22	5.00	26.34
Column Totals	26.30	28.85	28.85	28.12	23.62	29.75	33.80	36.60	235.89

Table "H" Marketable Early Yields by Plots in Pounds

Columns	1	2	3	4	5	6	7	8	Row Totals
Rows									
A	5.00	1.75	4.17	4.70	0.32	2.28	4.43	4.20	26.85
B	1.72	2.40	5.19	2.64	2.91	5.38	5.48	2.80	28.52
C	0.94	6.94	3.20	5.48	2.27	3.68	6.48	7.10	36.09
D	5.20	3.95	4.74	2.42	1.32	6.48	5.11	2.04	31.26
E	3.98	0.56	1.59	1.65	4.37	4.38	3.61	5.08	25.22
F	3.93	5.29	3.18	5.31	2.80	1.52	0.19	7.34	29.56
G	4.49	4.11	2.94	5.59	5.39	0.00	3.73	2.35	28.60
H	0.60	3.30	3.59	0.00	3.47	5.97	4.22	4.05	25.20
Column Totals	25.86	28.30	28.60	27.79	22.85	29.69	33.25	34.96	231.30

Table "J" Fruit Size Average from Two Prime Harvests given in Grams by Plots

Columns	1	2	3	4	5	6	7	8	Row Totals
Rows									
A	64	108	106	146	113	109	87	92	825
B	112	83	80	105	75	132	127	119	833
C	100	138	101	80	118	87	96	113	833
D	106	135	88	122	118	139	87	131	926
E	173	117	87	118	101	84	160	84	924
F	179	99	118	125	88	97	103	82	891
G	92	84	117	101	124	110	110	97	835
H	115	101	74	124	155	104	98	121	892
Column Totals	941	865	771	921	892	862	868	839	6959

Table "K" Average Fruit Shape-Index of each Plot Computed from the Marketable Yield of Two Prime Harvests

Columns	1	2	3	4	5	6	7	8	Row Totals
Rows									
A	0.95	1.00	1.07	1.07	1.26	1.06	1.01	1.10	8.52
B	0.97	1.22	1.06	1.01	0.94	1.01	1.03	1.03	8.27
C	1.28	1.07	1.01	0.96	1.06	1.01	1.06	1.04	8.49
D	1.10	1.03	1.02	1.05	1.01	1.09	0.94	1.20	8.44
E	1.09	1.03	1.19	1.03	1.04	0.98	1.09	1.02	8.47
F	1.06	1.02	0.94	1.03	0.98	0.98	1.16	0.96	8.13
G	1.02	0.94	1.00	1.11	1.01	1.24	0.95	0.95	8.22
H	1.04	1.00	0.97	1.30	1.02	1.11	1.01	1.03	8.48
Column Totals	8.51	8.31	8.26	8.56	8.32	8.48	8.25	8.33	67.02

Table "L" A Summary of the Significance of Mean Values Found for Total Yields, Total Marketable Yields, Total Early Yields, Marketable Early Yields, Fruit Size and Fruit Shape, in the Four Pairs of Reciprocal Hybrids Studied

F_1 Hybrids	Characteristics Studied					
	Total Yields (lb.)	Total Mark.* Yields	Total Early Yields	Mark. Early Yields	Fruit Size (gm.)	Fruit Shape Index
Redskin x Farthest North . . .	8.41	7.92	0.97	0.93	106	1.231
Farthest North x Redskin . . .	15.22	13.46	4.79	4.74	79	0.955
Redskin x Earliana	19.33	16.96	5.37	5.22	132	1.052
Earliana x Redskin	15.56	13.75	4.43	4.38	142	1.040
Redskin x Harkness	8.90	8.52	2.22	2.22	106	0.995
Harkness x Redskin	8.65	8.49	2.23	2.23	116	1.020
Redskin x Early Chatham . . .	14.11	13.29	4.04	3.89	91	1.009
Early Chatham x Redskin . . .	19.47	17.78	5.43	5.29	97	1.075
Significant Diff. at 5% level .	2.80	2.74	0.99	1.01	12	0.027
Significant Diff. at 1% level .	3.74	3.66	1.32	1.35	16	0.036

* Marketable