fungicide and largely avoids their weaknesses. Better control of gray leaf spot and Botrytis gray mold (including the ghost spot phase of Botrytis infection) should result, without jeopardizing control of late blight or causing plant injury and reducing yields. The combination of maneb and Dyrene is expected to control all the fungus diseases of tomato foliage under most conditions except those favoring severe disease development. In the event of an epidemic of a given disease, the fungicide most effective against it should be increased to the amount normally used and the interval between applications shortened. Suggestions for adjusting the program according to different disease situations are presented in Table 2. It is believed this program will be applicable in all the tomato-growing areas of the state.

There are certain situations where the combination of maneb and Dyrene would not be advantageous. For example, on the marl soils of Dade County where late blight is the main disease affecting tomatoes and gray leaf spot occurs sporadically, only maneb should be used. Use of the combination of maneb and Dyrene would not be beneficial on gray leaf spot resistant varieties except if Botrytis gray mold threatened the crop.

The success of any fungicidal program depends on the thoroughness of coverage and timeliness of application. This is also true for the program we suggest. For best results, applications should be started before diseases appear and continued regularly. This is particularly important in the control of Botrytis gray mold and gray leaf spot because good control depends on the build-up of a fungicidal deposit on the lower leaves before the vines "fall-over.”

LITERATURE CITED

INHERITANCE OF RADIAL FRUIT CRACKING IN A TOMATO CROSS

H. W. Young
Assistant Horticulturist
North Florida Experiment Station
Quincy

Fruit cracking is one of the primary causes of reduced quality and market value in tomato crops. Even though a considerable reduction in both incidence and degree of cracking can be obtained by the use of improved cultural methods, it would be desirable to breed a tomato variety that would exhibit fruit cracking resistance under many environmental conditions. Previous research indicated that cracking resistance, as found in some breeding lines, might be inherited. Reynard’s (1) work presented genetic information of some practical use to the breeder.

Because fruit cracking is sometimes serious

in Florida and will probably increase in importance as more acreage is harvested in the ‘pink’ stage of maturity, it is deemed appropriate to present the results of three years’ previously unpublished work in Ohio (Young (2)). Some of the material used in the Ohio study was grown in the fall of 1958 and the spring of 1959 at the North Florida Experiment Station and the cracking responses were similar to those in Ohio.

Although the study included three types of fruit cracking (radial, concentric and bursts), this paper will be confined to the data on radial cracking. Radial cracks may be defined as those cracks occurring on the stem end of the fruit extending distally from the corky layer at the point of attachment of the fruit and pedicel. Under most production situations radial cracking is usually the most serious type.

METHODS AND MATERIALS

Preliminary studies indicated that the breeding line Alabama 10-1 possessed resistance to
cracking. Furthermore, in several test crosses with Alabama 10-1, the F2 populations appeared to segregate for cracking resistance. Based on this preliminary information the specific objectives of the study were to determine whether cracking resistance in Alabama 10-1 is inherited and if so, to determine the mode of inheritance so that this information could be utilized in a practical breeding program. Alabama 10-1 was particularly suited for this type of study because it possessed several characteristics which were known to be determined by recessive genes.

Proceeding on the assumption that cracking resistance is inherited a cracking susceptible parent (Marglobe), which possessed several characteristics of known genetic inheritance (dominant alleles of genes present in Alabama 10-1) was selected as the other parent to assist in the determination of the mode of inheritance and to establish possible linkage relationships.

As stated above, the two parent lines were Alabama 10-1, hereafter designated as P1, and a Marglobe strain, hereafter designated as P2. P1 was developed at Auburn, Alabama, and seed was obtained from F. E. Johnstone, Jr. P2 was characterized by a determinate type of plant habit, rather weak vegetative growth, compound inflorescences, five or more fruits per cluster, uniform unripe fruit color (uu genes), pink ripe fruits of rather small size, and an average of about three locules per fruit. P2 was originally commercial seed from F. H. Woodruff and Sons Seed Co. It was characterized by an indeterminate type of plant, rather heavy vegetative growth, simple raceme inflorescences, three to five fruits per cluster, dark green shouldered unripe fruit color, red ripe fruits of medium size, and an average of more than five locules per fruit.

At the time the P1 and P2 were obtained they were considered to be genetically homozygous. Individual plants were selfed each year to maintain homozygosity of the parental lines. Crosses were made yearly to produce the F1 (P1 x P2), the F2 (F1 selfed), the BC to P1 (F1 X P1), and the BC to P2 (F1 X P2).

Water was applied by an overhead irrigation system only when the soil reached a low moisture level as indicated by plants showing visible signs of wilting during the morning hours. Because water supply was below optimum for fruit size the diameter of the fruit was considerably smaller than would be expected from a commercial crop that had been irrigated more frequently. By irrigating only after periods of soil moisture deficiency, together with pruning to one stem, it was possible to obtain considerable fruit cracking in each of the three years.

**Radial cracks**

Each fruit was individually examined and classified as to the length and depth of the cracks. The length of the cracks was measured in millimeters and the depth recorded as very deep, deep, shallow or very shallow. From the above data a radial crack index was arbitrarily established and each crack assigned an index number. Any fruit without cracks was given an index of 0. The crack index for each fruit was the sum of all its radial crack index numbers. The plant crack index was calculated by adding the crack indices of all its fruits and then dividing by the total number of fruits recorded for the plant.

**Data on other characters**

Because of their possible value in determining linkage relationships, data were taken on several other characters. Each plant was classified as to red or pink fruit color, uniform unripe or dark green shouldered unripe fruit color, indeterminate or determinate plant growth habit and number of fruits per plant. In addition, all fruits examined during the harvest period were classified as to locule number and the average number of locules per fruit for each plant. Furthermore, a size grading system was used in which the diameter of each fruit was recorded in 0.5 centimeter gradations.

**Results**

**Percentage of fruits with cracks**

There was a marked difference between the parental means for percentage of fruits with cracks (Table 1). The percentage of fruits in the P1 with cracks may appear rather high, for a supposedly crack resistant line. However, the P1 data recorded for the years 1951, 1952 and 1953 respectively show only 14 per cent, 14 per cent and 9 per cent of the fruits with cracks over five millimeters in length. Even though a fruit had only one crack two millimeters in length and very shallow the fruit was still recorded as cracked. On the other hand cracks appearing on the P2 fruits were all over five millimeters in length and quite deep.
Although the incidence of cracks varied from year to year the relationships between the various populations remained similar. In each of the years the F₁ and F₂ means were much closer to the P₂ mean than the P₁ mean suggesting the recessive inheritance of resistance to cracking.

**Crack Index**

The crack index for each plant, was calculated by totalling the index number of all fruits of a plant and then dividing by the total number of fruit harvested. The lower the index number the less the severity of cracking. The parental means for crack index for each of three years were statistically different at the 1% level of probability (Table 2). By the use of this index a better comparison of the degree of cracking was obtained.

**Average number of cracks per fruit**

The parental means for average number of cracks for each of the three years (Table 3) were statistically different at the 1% level of probability. Here again, although the means varied from year to year the relationships of the various populations remained quite constant.

**Discussion of results**

All of the evidence indicated that with each of the three measurements of cracking the resistance appeared to be controlled by recessive genes. Statistical tests suggested that with the crack index and percentage of fruits with cracks inheritance was controlled by two major gene pairs. However, in considering the average number of cracks per fruit four major pairs were indicated. This might seem inconsistent unless it is recognized that there was association with locule number, which was controlled by two pairs of genes in this particular cross.

As determined by chi-square tests for independence applied to data for the segregating populations the three measurements of cracking were associated with plant growth habit, ripe fruit color, number of ripe fruit, number of locules and fruit diameter. These interactions of characters are listed in Table 4.

**Table 2. Mean values for radial crack index per fruit for each generation for each of three years.**

<table>
<thead>
<tr>
<th>Year</th>
<th>F₁</th>
<th>F₂</th>
<th>P₁</th>
<th>P₂</th>
<th>BC to P₁</th>
<th>BC to P₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>1951</td>
<td>1.06</td>
<td>1.3</td>
<td>1.59</td>
<td>1.1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1952</td>
<td>0.58</td>
<td>0.95</td>
<td>2.25</td>
<td>2.3</td>
<td>1.12</td>
<td>-</td>
</tr>
<tr>
<td>1953</td>
<td>0.89</td>
<td>1.23</td>
<td>2.66</td>
<td>-</td>
<td>1.68</td>
<td>3.45</td>
</tr>
</tbody>
</table>

As indicated by the data the incidence (percentage of fruits with cracks) and overall severity (cracking index) appeared to be controlled by two major gene pairs. The distribution of phenotypic class groups could be predicted on the basis of a two-gene hypothesis (Tables 5 and 6). Both of the recessive genes for cracking resistance were found to be present in F₁. The genetically heterozygous F₂ exhibited an intermediate phenotype which appeared particularly susceptible to environmental conditions. One gene pair was con-
cluded to be associated with the plant growth habit genes Sp sp. Furthermore the other gene pair was concluded to be associated with ripe fruit color genes Y y. This two-gene hypothesis was applied to the two systems (Tables 5 and 6) used as measures of cracking and it was found to apply equally well to either system. These two systems differ in that the percentage of fruits with cracks is qualitative and gives a measure of the incidence of cracking, while the crack index is both qualitative and quantitative. The latter system more nearly describes the cracking situation as it existed in the parental lines and their progeny.

**TABLE 5. Theoretical distribution of expected and observed means of given generations for percentage of fruits with radial cracks with the hypothesis that the contribution of the various genotypes (based on the P<sub>1</sub> mean) was C<sub>rcrRlRl</sub> 100%, C<sub>crcrRlrl</sub> 90% and C<sub>cercrRlrl</sub> 50%.

<table>
<thead>
<tr>
<th>Generation</th>
<th>Observed mean</th>
<th>Expected mean</th>
<th>Genotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>P&lt;sub&gt;1&lt;/sub&gt;</td>
<td>57</td>
<td>68</td>
<td>cr&lt;sup&gt;c&lt;/sup&gt;cr&lt;sup&gt;r&lt;/sup&gt;Rl&lt;sup&gt;r&lt;/sup&gt;Nl&lt;sup&gt;r&lt;/sup&gt;</td>
</tr>
<tr>
<td>P&lt;sub&gt;2&lt;/sub&gt;</td>
<td>60</td>
<td>86</td>
<td>CrcrRlrl</td>
</tr>
<tr>
<td>F&lt;sub&gt;2&lt;/sub&gt;</td>
<td>75</td>
<td>65</td>
<td>All types</td>
</tr>
<tr>
<td>BC to P&lt;sub&gt;2&lt;/sub&gt;</td>
<td>74</td>
<td>78</td>
<td>All types</td>
</tr>
</tbody>
</table>

**TABLE 6. Observed percentages of plants falling into each of the radial crack index class groups as compared with the expected percentage of plants using the two-gene pair hypothesis, and with the assumption that the genotypes were cercr<sup>r</sup>rl<sup>r</sup>, (P<sub>2</sub>), CrcrRlrl (P<sub>2</sub>) and Cercr<sup>r</sup>r<sup>l</sup>rl (P<sub>1</sub>.

<table>
<thead>
<tr>
<th>Percentage of plants falling into each class group</th>
<th>Observed percentages of plants.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>Class</td>
</tr>
<tr>
<td>------------</td>
<td>-------</td>
</tr>
<tr>
<td>P&lt;sub&gt;1&lt;/sub&gt;</td>
<td>4-22</td>
</tr>
<tr>
<td></td>
<td>31-112</td>
</tr>
<tr>
<td>P&lt;sub&gt;2&lt;/sub&gt;</td>
<td>4-22</td>
</tr>
<tr>
<td></td>
<td>31-112</td>
</tr>
<tr>
<td></td>
<td>31-112</td>
</tr>
<tr>
<td>P&lt;sub&gt;1&lt;/sub&gt;</td>
<td>4-22</td>
</tr>
<tr>
<td></td>
<td>31-112</td>
</tr>
<tr>
<td>P&lt;sub&gt;2&lt;/sub&gt;</td>
<td>4-22</td>
</tr>
<tr>
<td></td>
<td>31-112</td>
</tr>
</tbody>
</table>

**DISCUSSION**

Selection of crack resistant lines on the basis of crack index would appear to offer the best evaluation of the crack resistance of a variety, since it takes into account both the incidence and the degree of cracking. On the other hand, selection on the basis of the incidence of cracks (percentage of fruit with cracks) would provide a saving of time.

That cracking resistance is inherited as a recessive character was evidenced in means of the F<sub>1</sub>, BC to P<sub>1</sub> and BC to P<sub>2</sub> which were nearer to the P<sub>1</sub> means. Further evidence of recessiveness was found in the very small number of F<sub>2</sub> plants with the cracking resistance of the P<sub>1</sub>. Because of its recessive nature, high resistance to cracking would be practically impossible to obtain in an F<sub>1</sub> variety, unless both parents possessed genes for resistance.

**CONCLUSIONS**

Radial cracking was found to be determined by two major gene pairs, designated as cr cr and rl rl. Crack resistance genes were found to be associated with pink fruit color, high number of fruits per plant, low average number of locules per fruit, small fruit diameter, and determinate plant growth habit.

Because of the recessive nature of cracking resistance and its association with certain undesirable characters such as few locules per fruit and small fruit diameter, it is suggested that large F<sub>2</sub> and Backcross populations might be needed to isolate recombination types.

Further study is necessary to substantiate the results of this work and to determine more precise linkage relationships. This work is now in progress at the North Florida Experiment Station.

**ACKNOWLEDGMENTS**

The writer gratefully acknowledges the aid and advice of Drs. F. S. Howlett, E. K. Alban and W. N. Brown of the Department of Horticulture, Ohio State University and Dr. F. E. Johnstone, Jr. of the Department of Horticulture, University of Georgia, The financial assistance provided by the Helena Chamberlain Fellowship Fund is also gratefully acknowledged.

**LITERATURE CITED**
