Susceptibility and Inheritance of Susceptibility to Peach Leaf Curl in Peach and Nectarine Cultivars

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ABSTRACT

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During the spring of 1980, 67 peach and 11 nectarine cultivars were evaluated for susceptibility to peach leaf curl. No cultivar was immune; susceptibility varied greatly, however, and a wide range of symptoms was observed. Analysis of 862 progeny seedlings synthesized from 13 matings indicated that leaf curl susceptibility was heritable. Regression of progeny performance on average parental performance was $b = 0.34 \pm 0.19$. Redhaven and most cultivars derived from Redhaven were tolerant to leaf curl, whereas Redskin and cultivars derived from Redskin were susceptible or highly susceptible.

Peach leaf curl, caused by *Taphrina deformans* (Berk.) Tul., affects peaches and nectarines in most regions of the world where these fruits are grown (2,8). Severe infection can reduce fruit quality and fruit-set and yield and weaken trees as a result of severe defoliation. Leaf curl is most severe in years when cool, wet weather occurs during bud swell to bud opening (2,8). This disease can be controlled with a single fungicide application before bud swell (2,11). Chemical control has been so effective that little effort has been directed toward breeding for resistance. Few published reports describe the susceptibility of peach and nectarine cultivars to *T. deformans* (1,6), and genetic analysis of susceptibility to leaf curl has not been reported.

During the spring of 1980, there was a moderate to severe leaf curl epiphytotic at the Sandhills Research Station, Jackson Springs, NC, where a major portion of the North Carolina peach breeding program is located. This afforded us an opportunity to evaluate the susceptibility of numerous peach and nectarine cultivars, selections, and seedlings to *T. deformans*, to observe differences in symptomology, and to study the inheritance of leaf curl susceptibility. This paper reports the results and analysis of these observations.

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MATERIALS AND METHODS

Leaf curl susceptibility rating. All peach and nectarine cultivars and selections were rated during 7 days between 22 and 29 April 1980, approximately 4 wk after full bloom. Progeny seedlings were rated on 5 May. The amount of infection was rated as the percent of leaves with symptoms.

The susceptibility rating scale was: 0 = no symptoms, 1 = chlorosis without leaf thickening or puckering, 2 = chlorosis with areas less than 1.0 cm in diameter exhibiting mild leaf puckering, 3 = mild puckering and slight leaf thickening of less than 25% of the leaf surface, 4 = leaf thickening and puckering of 25–50% of the leaf surface, 5 = leaf thickening and extensive puckering of 50–100% of the leaf surface, 6 = leaf thickening, extensive puckering and curling of 25% of the leaf, 7 = extensive leaf thickening, puckering, and curling of 25–50% of the leaf, 8 = extensive leaf thickening, puckering, and curling of 50–75% of the leaf, 9 = entire leaf extensively thickened, puckered, and curled, making it two to three times the size of an uninfected leaf.

Between two and 65 trees per cultivar were observed. Many cultivars were located in several fields in a 200-ha area. The entire tree was observed; affected leaves were given an average rating and the percent of leaves infected was estimated. Trees that received fungicides in 1979 were evaluated separately from those that did not receive fungicides.

Inheritance of leaf curl susceptibility. The pedigree of the 14 peach cultivars developed in North Carolina was constructed and used to study inheritance patterns of leaf curl susceptibility. Pedigree information was obtained from several sources (4,5,10). Leaf curl susceptibility of the pedigree members was obtained from ratings taken at the Sandhills Research Station in 1980 and from ratings after a 1951 epiphytotic in South Carolina (6). Data for the genetic analysis of progeny were obtained from evaluation of 862 seedlings synthesized from 13 matings. None of these seedlings had received fungicides. These data were analyzed by regressing the progeny performance on the average performance of their parents to determine the genetic contribution of peach leaf curl expression (3).

Fungicides. No dormant sprays were applied before the 1979 or 1980 growing seasons. Trees that were sprayed during the 1979 growing season were sprayed with wettable sulfur (13.5 kg/ha [12.0 lb/acre]) for the shuck-fall and cover sprays at 2-wk intervals; benomyl (0.57 kg a.i./ha [0.5 lb a.i./acre]) was combined with captan (2.25 kg a.i./ha [2.0 lb a.i./acre]) in the preharvest sprays. The number of applications depended on ripening date. The insecticides used were either parathion or azinphos-methyl.

RESULTS AND DISCUSSION

No peach or nectarine cultivar was immune to *T. deformans*, but susceptibility varied greatly (Table 1). Symptoms were not observed on the nectarine cultivars Nectared 6 and Lafayette; these may have been escapes, but more likely no infection occurred because these trees had been sprayed during the 1979 growing season. Northover reported that preharvest sprays of captan can result in leaf curl control the following spring (9).

Our data suggested that nectarines were more susceptible than peaches; all nectarine cultivars except Nectared 6 and Lafayette were either susceptible or highly susceptible (Table 1). These observations contrast with those of Ackerman (1), who concluded that nectarines are less likely than peaches to be severely infected. The small number of cultivars we evaluated prohibits any conclusive statement.

Where we observed the same peach cultivars as those observed by Foster and Petersen (6), results were similar after extrapolation between the two rating systems. Redhaven was tolerant and Redskin highly susceptible. Two major exceptions were Loring and Sunhigh; we rated these peach cultivars as highly

Table 1. Susceptibility of peach and nectarine cultivars to *Taphrina deformans* in 1980

Cultivar	Susceptibility[a]	Leaves with symptoms (%)	Trees (no.)	Bloom, 25 March (%)
Peach				
	Fungicide treatment[b]			
Early Redhaven	0.3 ± 0.5	1.0 ± 1.0	4	...
Kirkman Gem	0.5 ± 0.6	1.0 ± 1.0	4	...
Dixiland	0.5 ± 0.6	1.0 ± 1.0	3	...
Clayton	0.8 ± 0.8	2.0 ± 0.5	53	10
Com-pact Redhaven	0.8 ± 1.1	1.0 ± 0.6	5	...
Ellerbe	1.0 ± 0.5	2.0 ± 1.0	40	...
Vivid	1.3 ± 0.6	1.0 ± 0	3	...
Correll	1.3 ± 1.3	1.0 ± 1.0	25	50
Parade	1.5 ± 0.7	1.0 ± 0	2	...
Candor	1.5 ± 1.3	3.0 ± 1.0	21	5
Rubired	1.7 ± 1.0	3.0 ± 2.0	25	...
Pekin	1.8 ± 0.8	2.0 ± 1.5	35	25
Redhaven	1.9 ± 0.7	5.0 ± 2.0	15	30
McNeely	2.0 ± 0	2.0 ± 1.0	2	...
Surecrop	2.0 ± 0.8	5.0 ± 4.0	4	...
Whynot	2.0 ± 1.0	4.0 ± 2.5	11	0
Everts	2.0 ± 1.2	2.0 ± 1.0	4	...
Emery	2.3 ± 0.6	3.0 ± 2.0	10	20
Andross	2.3 ± 1.5	1.0 ± 1.0	4	...
Gem	2.3 ± 2.5	1.0 ± 0.6	3	...
Dixon	2.5 ± 1.9	2.0 ± 1.0	4	...
Belle of Georgia	2.7 ± 0.6	10.0 ± 0	3	...
Derby	2.7 ± 1.5	2.0 ± 1.0	25	80
Sunqueen	3.3 ± 2.6	3.0 ± 2.0	4	...
Ranger	3.4 ± 0.5	7.0 ± 3.0	8	0
Hamlet	3.4 ± 1.8	4.0 ± 2.3	24	20
Springbrite	3.5 ± 0.8	16.0 ± 7.0	3	...
Elberta	3.6 ± 1.9	13.0 ± 5.0	11	...
Lovell	3.8 ± 1.3	3.0 ± 2.0	4	...
Monroe	4.0 ± 0	2.0 ± 0	3	...
Fairtime	4.0 ± 0.6	15.0 ± 6.0	6	...
Harvester	4.3 ± 0.5	13.0 ± 5.0	4	...
Blake	4.3 ± 1.7	6.0 ± 4.0	4	...
Velvet	4.4 ± 0.6	26.0 ± 9.0	5	...
Rio-Oso-Gem	4.4 ± 0.9	11.0 ± 6.0	5	70
Winblo	4.8 ± 0.4	24.0 ± 5.0	65	40
Biscoe	5.0 ± 2.0	2.0 ± 1.4	7	...
Sunbrite	5.0 ± 0	3.0 ± 2.0	3	...
Junegold	5.0 ± 0	27.0 ± 6.0	3	...
Cary Mac	5.0 ± 0	18.0 ± 4.0	2	...
Autumn Gem	5.0 ± 0	20.0 ± 0	3	...
Redglobe	5.0 ± 0.6	8.0 ± 3.0	6	...
Norman	5.0 ± 0.6	16.0 ± 4.5	28	...
Flavorcrest	5.3 ± 0.6	10.0 ± 5.0	3	...
Loring	5.4 ± 0.5	45.0 ± 5.0	15	...
Firebrite	5.5 ± 0.6	9.0 ± 2.5	4	...
Troy	5.5 ± 0.7	15.0 ± 2.0	9	...
Camden	5.6 ± 0.8	36.0 ± 5.0	7	...
Redskin	5.7 ± 0.7	25.0 ± 5.0	38	...
Sunhigh	5.7 ± 1.5	5.0 ± 0	6	...
Windsor	6.0 ± 0	20.0 ± 0	2	...
	No fungicide treatment			
Reliance	2.0 ± 0	35.0 ± 7.0	2	5
Southland	2.0 ± 0	2.0 ± 2.0	3	95
Carson	2.5 ± 0.7	15.0 ± 7.0	2	0
Jefferson	3.0 ± 0	17.0 ± 6.0	3	10
Novelred	3.0 ± 0	37.0 ± 6.0	3	10
Dixired	4.0 ± 0.6	37.0 ± 6.0	3	10
Marsun	4.0 ± 0	30.0 ± 10.0	3	10
Starlite	5.0 ± 0.5	50.0 ± 0	3	100
Babygold #8	5.0 ± 0	20.0 ± 10.0	3	10
Suncrest	5.0 ± 0	30.0 ± 0	2	...
Flamecrest	6.0 ± 0.6	40.0 ± 0	2	90
Regina	6.0 ± 1.4	45.0 ± 7.0	2	...
Summerset	6.0 ± 0	40.0 ± 0	2	90
Late Legrand	6.5 ± 0.7	45.0 ± 2.0	2	30
Early Sungrand	7.0 ± 0	45.0 ± 7.0	2	70
Springcrest	7.7 ± 0.6	70.0 ± 10.0	3	100

(*continued on next page*)

Table 1. *(continued from preceding page)*

Cultivar	Susceptibility[a]	Leaves with symptoms (%)	Trees (no.)	Bloom, 25 March (%)
Nectarine				
	Fungicide treatment[b]			
Nectared 6	0	0	3	...
Lafayette	0	0	2	...
Nectared 4	2.0 ± 1.4	1.0 ± 0.7	2	...
Columbia	2.3 ± 0.5	1.0 ± 0	4	...
	No fungicide treatment			
Harko	2.5 ± 0.7	25.0 ± 7.1	2	5
Flavortop	5.0 ± 1.7	30.0 ± 10.0	3	10
Rose	6.0 ± 0	40.0 ± 0	2	70
Nectared 7	6.7 ± 0.6	37.0 ± 5.8	3	40
Earliblaze	7.3 ± 1.2	43.0 ± 12.0	2	10
Flamekist	7.5 ± 0.7	50.0 ± 14.1	2	95
Fantasia	8.0 ± 0	50.0 ± 0	3	30

[a] Rated on a 0–9 scale, with 0 = no visible symptoms. Ratings of 0.1–1.9 are considered tolerant, 2.0–4.9 susceptible, and 5.0–9.0 highly susceptible. The standard deviation is among observations for each cultivar.

[b] Fungicides used during the 1979 growing season were wettable sulfur (13.5 kg/ha [12.0 lb/acre]) for the shuck-fall and cover sprays at 2-wk intervals; benomyl (0.57 kg a.i./ha [0.5 lb a.i./acre]) was combined with captan (2.25 kg a.i./ha [2.0 lb a.i./acre]) in preharvest sprays. The number of applications depended on ripening date.

susceptible while Foster and Petersen (6) rated them as tolerant or moderately susceptible. Observations in growers' orchards also support the hypothesis that Redhaven is tolerant to leaf curl and Redskin is highly susceptible.

Cultivars that leaf out and bloom early might be more susceptible than cultivars that initiate growth later because they escape the early cool, wet weather most conducive for infection. Although many susceptible cultivars bloomed early, other susceptible cultivars bloomed late (Table 1). This suggests that factors other than time of bloom are involved in susceptibility to leaf curl, as Ackerman also observed (1).

By June, most affected leaves had abscised. Peach cultivars that had a high percentage of infected leaves dropped many fruits, causing yield reduction. Fruits on Redskin peach were the most severely affected, but seldom did more than 1% of the fruit per tree show symptoms.

We interpreted the large range of symptom severity as susceptibility differences. Symptoms on the more tolerant peach cultivars such as Redhaven and Clayton were limited to the earliest emerging leaves. Leaves on tolerant cultivars did not exhibit the typical hypertrophic symptoms of leaf thickening, puckering, and curling. The predominant symptom was the development of a yellow to red discoloration on only the earliest emerging leaves and subsequent leaf drop. The time of development of these symptoms coincided with the maximal symptom expression by the highly susceptible cultivars.

Significant regression effects ($P = 0.05$) were detected between midparent values and progeny mean values (Table 2), indicating that peach leaf curl susceptibility was heritable. Linear regression of progeny performance on the average performance of their parents was $b = 0.34 \pm 0.19$. This estimate reflects the degree of additive genetic effects controlling trait expression in this set of matings and can be loosely interpreted as narrow-sense heritability. However, because the progeny evaluated were not generated at random from a base population in Hardy-Weinberg equilibrium, this estimate cannot be strictly interpreted as narrow-sense heritability. The data suggest that significant gain could be realized by selecting resistant individuals. Hansche et al (7) speculated that additive genetic variability is a major component of most commercially important traits in peach. Our results lend support to this hypothesis because our data suggest that a large component of leaf curl expression is controlled by additive genetic effects. Our data do not allow any conclusions about the role of dominance effects controlling leaf curl expression.

Because the data indicated that leaf curl susceptibility was heritable, the pedigree of the 14 North Carolina peach cultivars was used to investigate their leaf curl susceptibility in relation to that of their pedigree members (Fig. 1). Cultivars having Redskin as one parent were susceptible or highly susceptible; Emery was the least susceptible. All cultivars with Redhaven as a parent, except Hamlet, were rated as tolerant. Thirteen

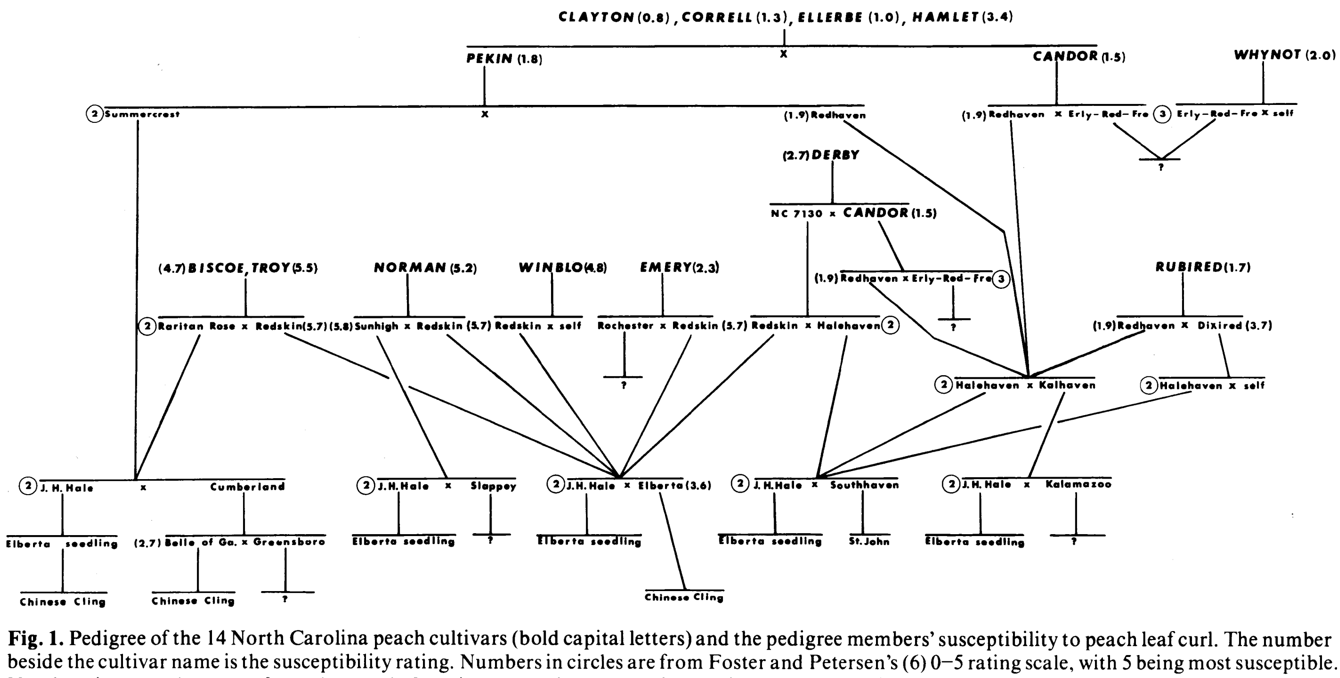

Fig. 1. Pedigree of the 14 North Carolina peach cultivars (bold capital letters) and the pedigree members' susceptibility to peach leaf curl. The number beside the cultivar name is the susceptibility rating. Numbers in circles are from Foster and Petersen's (6) 0–5 rating scale, with 5 being most susceptible. Numbers in parentheses are from the North Carolina 0–9 rating scale, with 9 being most susceptible.

Table 2. *Taphrina deformans* susceptibility ratings[a] for midparent values and for progeny mean values of 13 peach matings

Mating	Midparent	Progeny mean
Biscoe × Pekin	3.25	3.62
Emery × Candor	1.90	3.59
Biscoe × Emery	3.50	4.62
Biscoe × Norman	4.95	4.78
Biscoe × Candor	3.10	3.40
Biscoe × Starlite	5.00	4.22
Emery × Pekin	2.05	3.83
Emery × F90-17	3.90	4.28
Emery × Fairtime	3.65	4.09
Emery × Rio-Oso-Gem	3.35	3.20
Babygold #8 × Ellerbe	3.00	2.90
Ellerbe × Fairtime	3.00	3.36
Babygold #8 × Winblo	4.90	4.20

[a] On a 0–9 scale, with 0 = no visible symptoms. Ratings of 0.1–1.9 are considered tolerant, 2.0–4.9 susceptible, and 5.0–9.0 highly susceptible.

of the North Carolina cultivars have either J. H. Hale or Elberta, or both, in their pedigree; Whynot's pedigree cannot be completed since the parentage of Erly-Red-Fre is not known. At this level of the pedigree, often the pollen parent and cultivar susceptibility to leaf curl are not known. Thus, any conclusions drawn beyond the level of J. H. Hale and Elberta would be speculative. Similar pedigrees could be constructed for other cultivars, using the data in Table 1 and that of Foster and Petersen (6).

Generally, the cultivars most tolerant to leaf curl are also the most tolerant to bacterial spot (caused by *Xanthomonas pruni*) and have a slow rate of flesh browning (4). Whether this is only correlative or is the result of biological relationships is not known.

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LITERATURE CITED

1. Ackerman, W. L. 1953. The evaluation of peach leaf curl in foreign and domestic peaches and nectarines grown at the U.S. Plant Introduction Garden, Chico, Calif. Bur. of Plant Industry, Soils, and Agric. Eng., USDA (mimeo). pp. 1-31.
2. Anderson, H. W. 1956. Diseases of Fruit Crops. McGraw-Hill Book Co., Inc., New York. 501 pp.
3. Bohren, B. B., and McKean, H. E. 1961. Relative efficiencies of heritability estimates based on regression of offspring in parent. Biometrics 17:481-491.
4. Clayton, C. N., Correll, F. E., Ballington, J. R., and Worthington, S. M. 1976. Four new peach varieties in North Carolina. N.C. Agric. Exp. Stn. Bull. 454. 10 pp.
5. Cullinan, F. P. 1937. Improvement of stone fruits. Pages 665-748 in: Yearbook of Agriculture. U.S. Government Printing Office, Washington, DC. 1,497 pp.
6. Foster, H. H., and Petersen, D. H. 1951. The peach leaf curl epidemic of 1951. Plant Dis. Rep. 36:140-141.
7. Hansche, P. E., Hesse, C. O., and Beres, V. 1972. Estimates of genetic and environmental effects on several traits in peach. J. Am. Soc. Hortic. Sci. 97:76-79.
8. Mix, A. J. 1935. The life history of *Taphrina deformans*. Phytopathology 25:41-66.
9. Northover, J. 1978. Prevention of peach leaf curl, caused by *Taphrina deformans*, with preharvest and pre-leaf fall fungicide applications. Plant Dis. Rep. 62:706-709.
10. Savage, E. F., and Prince, V. E. 1972. Performance of peach cultivars in Georgia. Ga. Agric. Exp. Stn. Res. Bull. 114.
11. Wilson, E. E. 1937. Control of peach leaf curl by autumn applications of various fungicides. Phytopathology 27:110-112.