

## Increased Value of Resistance to Infection if Used in Integrated Pest Management Control of Tomato Curly Top

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### ABSTRACT

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Cultivars derived from the University of California tomato release VF145 have shown a tendency to escape the curly top disease caused by beet curly top virus. This resistance was much more effective under mild to moderate disease exposures, similar to those encountered in direct-seeded commercial fields, than under severe exposures in disease nurseries. Over a 13-yr period, in curly top nurseries at Prosser, WA, incidence of curly top in VF145 cultivars averaged 25% lower than in cultivars used to replace these VF145 cultivars in California. When considering only years of moderate exposure, however, the reduction in curly top by use of VF145 cultivars was 52%. The

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predominance of VF145 cultivars is suggested as an important component of the integrated pest management practices which greatly reduced curly top losses in California processing tomatoes during the last 30 yr. The disease-escaping ability of VF145 cultivars apparently was derived from cultivar Tiny Tim and is possessed by all VF145 cultivars tested. This disease-escaping ability of VF145 cultivars makes them particularly useful as parents in crosses with germ plasm having even higher levels of curly top resistance.

Prior to 1950, curly top, caused by beet curly top virus (BCTV) was a serious problem in fields of fresh market and processing tomatoes (*Lycopersicon esculentum* Mill.) in California (2). Since that time, BCTV has continued to cause some losses in transplanted fresh-market cultivars, but losses have been minimal in direct-seeded processing tomatoes.

The diminished curly top losses over the past 30 yr have resulted from application of several components of an integrated pest management (IPM) system that has naturally evolved and which minimizes losses from this devastating disease in California.

Since 1950, one component has been effective control of the sugar beet leafhopper vector (*Circulifer tenellus* Baker) in desert breeding grounds by insecticide spraying of weed host species prior to leafhopper migration (2). Most exposure of tomatoes to BCTV occurs during early-summer as leafhoppers migrate from desert weeds dying from water stress or maturity. Tomato is not a preferred host of the vector so leafhoppers do not reproduce or remain in tomato fields to provide for continuous spread of the virus. Many desert areas in California in which weed hosts formerly flourished are now cultivated. Efforts to control weeds on ditchbanks and waste areas have also been effective.

A second IPM component is the practice of direct seeding, a standard practice since the early 1950s for processing tomatoes and, to some extent, for fresh market tomatoes. This has greatly reduced curly top losses (9). In direct-seeded fields, young tomato plants infected during early season leafhopper migrations soon die and are overgrown by nearby plants which have escaped infection. This results in minimal, if any, yield losses, even when a substantial number of plants become infected (4,9,12). Dense canopies of direct-seeded plants also provide a shaded environment which is unattractive to the vector.

A third IPM component accounting for reduced curly top losses has not been recognized previously. Cultivars selected from the VF145 germ plasm released by the University of California in the

early 1960s have a tendency to escape BCTV infection (17). These cultivars were the principal machine-harvested tomatoes in California during the 1960s and 1970s. We have used them as standards of commercial acceptability in our disease screening and evaluation trials ever since they became available.

The resistance of VF145 cultivars is a mild expression of the passive or disease-escaping type described by Cooper and Jones (5). This type, characterized as resistant but infectible, has been reported previously in curly top-resistant breeding lines (14-19). Characterization studies have indicated that this resistance involves some leafhopper nonpreference (14,15,17) and does not involve disease tolerance, restricted translocation, localization at place of inoculation, or virus strain-specific reaction (16,18,19). It has been proposed that virus delivered by the leafhopper vector establishes infection less often in curly top-escaping lines than in more susceptible cultivars (16-18).

Symptoms of curly top disease of tomato are highly distinctive, easily identified, and seldom confused with those of other tomato diseases occurring in eastern Washington (18). Transmission from curly top-diseased plants in the field to diagnostic hosts over a 20-yr period have confirmed that visual symptoms are an accurate indicator of the presence of BCTV (*unpublished*). Serological indexing of host plant and soil has shown that other virus and soilborne diseases of tomato are present in this area. However, under conditions present in curly top disease nurseries, the predominant disease present in young plants previous to fruit ripening is curly top. An occasional outbreak of tomato yellow top virus occurs, but personnel trained in detecting curly top disease can easily recognize the difference.

This paper reports the level, mode of expression, and importance of the curly top-escaping ability of VF145 cultivars and the resulting usefulness of these cultivars as parents in breeding programs.

### MATERIALS AND METHODS

Tomato selections were seeded directly into plastic flats with molded cells in late March, thinned to one plant per cell a week after emergence, grown in a screenhouse until mid-May, and transplanted to fields near Prosser, WA, preceding the main migrations of the vector from desert areas into fields. Transplants

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were spaced 40 cm or 60 cm apart in rows 1 m apart with three rows of tomatoes placed between two single rows of previously established sugar beets (*Beta vulgaris* L.). The sugar beets served as a catch crop for migrating leafhoppers (9) and also as a reservoir of BCTV and viruliferous leafhoppers to which the nonpreferred tomatoes were increasingly exposed as the growing season progressed.

From mid-June until mid-September, incidence and severity of curly top was recorded at 10- to 20-day intervals. Disease severity was rated on a 0 to 5 scale with 0 = symptomless and 5 = dead from curly top. Individual plant ratings were totaled for each cultivar in each replication and divided by the number of plants to provide a disease index. Average plant disease indices or percent disease incidence for the season for each replication were used in statistical comparisons.

In 13 trials over 15 yr, the incidence and severity of curly top in VF145 cultivars was compared with that of a wide array of other commercial cultivars. Over the years, these trials included all available VF145 cultivars and most machine-harvest cultivars released in California and throughout the United States, supposedly having adaptability or other advantages over VF145 cultivars.

To provide a more accurate measure of their resistance, VF145 cultivars were also compared with the highly susceptible cultivar VR Moscow, and with our most resistant germ plasm release C5 (11) during 5 yr of testing, by planting eight replications of 14 plants of each line in each trial. In a sixth trial, the disease reactions of VF145 cultivars and VR Moscow were compared with that of Tiny Tim, the suspected source of VF145's ability to occasionally escape infection (1).

To test the effect of plant age and time of transplanting on expression of the resistance of VF145 cultivars, 6-wk-old seedlings were transplanted into the disease nursery at the normal time (17 May, when few leafhoppers were present) and on four subsequent dates. The first two, 24 and 31 May, were before or during

leafhopper migrations into the field. The last two transplanting dates were 11 June, when leafhoppers were becoming prevalent on interplanted sugarbeets, and 9 July, when large populations of active, viruliferous leafhoppers were present.

## RESULTS

Disease incidence and severity in VF145 cultivars was consistently lower than in other susceptible cultivars (Table 1). In these 13 yr, VF145 cultivars averaged a 25% lower incidence of curly top than other susceptible cultivars. Under very severe exposure, when less than 10% of the plants of most cultivars survived, from 10 to 20% of VF145 plants appeared healthy until harvest, but on the average the use of VF145 cultivars only reduced curly top incidence 7%. Under somewhat less severe exposure, when 10-30% of the plants of more susceptible cultivars remained symptomless, 30-40% of VF145 plants remained healthy and produced a crop, and the use of VF145 cultivars reduced curly top incidence an average of 19%. If years of only moderate exposure in these disease nurseries are separated from those discussed above, which had severe or very severe exposure, the use of VF145 cultivars reduced the incidence of curly top an average of 52%, a very significant amount.

In the direct comparison with the very susceptible VR Moscow cultivar, VF145 cultivars were significantly less susceptible in every test (Table 2) and averaged almost 27% less curly top than VR Moscow over a 5-yr period. However, VF145 cultivars were about 14% more susceptible than their parent, Tiny Tim, and much more susceptible than the highly-resistant C5 breeding line.

Time of transplanting played an important part in determining amount of curly top in VF145 cultivars (Fig. 1). Plants transplanted 9 July were exposed to BCTV infection 53 days less than those transplanted 17 May, but 98% of them were killed while 57% of those transplanted 17 May survived. The resistance to infection in VF145 cultivars apparently becomes more effective as plant age increases.

## DISCUSSION

Blood (3), Lesley (6), and Shapovalov and Beecher (13) demonstrated that some cultivars and exotic forms of *L. esculentum*, especially dwarf types, were less susceptible to BCTV than others under field conditions. Lesley (6) concluded that the least susceptible lines showed about 25% less curly top than more susceptible cultivars, about the same level of resistance expressed overall by VF145 cultivars in our studies. Dwarf cultivar Tiny Tim, a parent of VF145, was not tested by these earlier workers, but it expressed a significant disease-escaping ability (36% less disease than VR Moscow) in our studies (Table 2) and probably is the source of VF145's resistance.

TABLE 1. Effect of inoculation pressure on curly top disease incidence in VF145-derived tomato cultivars and in more susceptible commercial cultivars

Inoculum pressure	Year	Diseased plants (%) <sup>w</sup>		Reduction (%)
		VF145 cultivars <sup>x</sup>	Other cultivars <sup>y</sup>	
Very severe	1970	88	97	9
	1971	83	91	9
	1974	92	100	8
	1976	88	97	9
	1978	98	100	2
	Ave <sup>z</sup>	90	97	7
Severe	1968	62	84	26
	1969	71	93	24
	1972	71	87	18
	1975	66	71	7
	Ave <sup>z</sup>	68	84	19
Moderate	1973	45	70	36
	1979	41	63	35
	1980	29	81	64
	1982	13	45	71
	Ave <sup>z</sup>	32	65	52
	Overall Ave <sup>z</sup>	65	83	25

<sup>w</sup>Percentage of plants diseased by mid-September in transplanted field trials at Prosser, WA.

<sup>x</sup>VF145 cultivars consist mostly of VF145-21-4, VF145-22-8, VF145B-7879, VF145-513, and Pickrite, all of which performed in a similar manner.

<sup>y</sup>The more susceptible commercial cultivars tested were VR Moscow and selections of UC92, UC105, UC122, or UC134, along with other "square" machine-harvest types from the University of California and commercial seed companies in California.

<sup>z</sup>In a Studentized *t*-test, the differences among VF145 cultivars and more susceptible commercial cultivars under very severe, severe, and moderate disease exposure, was significant at the 1-5% level, as well as the overall difference.

TABLE 2. Mean curly top severity indices for different tomato cultivars in six field tests

Cultivar	Disease severity indices <sup>y</sup> in test number:						Mean <sup>w</sup>
	I	II	III	IV	V	VI	
VR Moscow	2.48 A <sup>x</sup>	2.55 A	1.72 A	3.71 A	3.67 A	4.36 A	3.08 A
VF145	1.93 B	1.90 B	0.94 B	3.07 B	2.41 B	3.19 B	2.24 B
C5	0.16 C	0.15 C	0.07 C	0.38 C	0.31 C	(1.55) <sup>y</sup>	0.44 C
Tiny Tim <sup>z</sup>							2.79 C

<sup>w</sup>Disease severity expressed by indices derived by rating each plant for curly top six to seven times during the season on a 0 to 5 scale with 0 = symptomless and 5 = death from curly top. These ratings were totaled and divided by number of readings and plants involved to give average disease expression per plant during the growing season. Each number represents the average of eight replications of 14 plants each.

<sup>x</sup>The combined results of the six tests were analyzed as a split-plot design with tests as whole plots and cultivars as subplots.

<sup>y</sup>Within tests, numbers not having a letter in common are statistically different according to Duncan's multiple range test ( $P = 0.01$ ).

<sup>z</sup>Computed missing plot.

<sup>z</sup>A parent of VF145, Tiny Tim, was entered in one test for comparison.

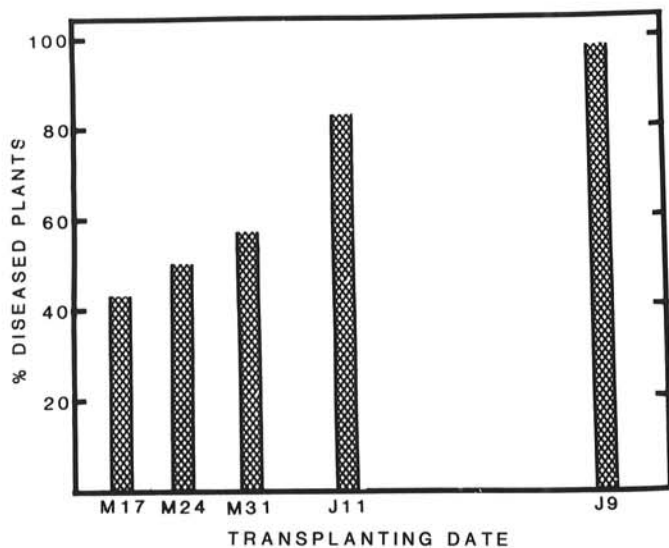


Fig. 1. Percent incidence of curly top at harvest of VF145 tomato plants that had been transplanted to a disease nursery three times in May (M17, M24, and M31), once in June (J11), and once in July (J9).

It is evident that resistance of VF145 cultivars was much more important under less intense, more nearly normal, exposures (Table 1). Since only mild to moderate exposures normally occur in commercial direct-seeded fields, the 52% average reduction in curly top when VF145 cultivars were grown under moderate exposures takes on much significance.

Other cultivars also consistently expressed some escaping ability in our tests, but these levels were lower than those of VF145 cultivars. Some cultivars that were identified with potentially useful levels were Pakmor, Campbell 28, VF10, VF13L, and UC82. There appeared to be some small differences in resistance among VF145 cultivars, but they all expressed similar levels of resistance compared to more susceptible cultivars.

Because VF145 cultivars have some resistance they have been particularly valuable breeding parents in crosses with C5 and other highly resistant but commercially unacceptable germ plasm. Because resistance to BCTV is controlled by several genes and is linked to undesirable horticultural characteristics (such as small, rough fruit [7,8,10]), it has been very difficult to combine with commercially-acceptable horticultural types. In crosses with VF145 cultivars, recombinations of acceptable horticultural type and moderate-to-high levels of BCTV resistance have been much more prevalent than in crosses with other more susceptible lines. Most of the curly top-resistant cultivars and germ plasm recently released from our program have VF145 cultivars in their parentage.

The importance of this genetic component in the California IPM approach to curly top control should not be underestimated. A renewed potential for serious curly top losses has emerged since VF145 cultivars have been replaced with very susceptible cultivars. This would be particularly true if vector control practices in California deserts were diminished because of environmental concerns. As part of the curly top disease management practices, this genetically-controlled escaping ability reduces the risk in plantings near areas harboring large leafhopper populations or in

plantings with poor emergence and thin stands. Such fields are particularly vulnerable to serious curly top losses. The expense and urgency of the second IPM component, insecticide spraying of leafhopper host species in desert areas, could be somewhat reduced by planting VF145 cultivars or cultivars with similar disease-escaping ability. An even greater impact would be obtained by planting lines with higher levels of resistance, such as those released by the USDA program at Prosser, WA. A number of fresh market and processing cultivars and breeding lines are now available that have commercially acceptable horticultural characteristics combined with resistance adequate for commercial production of tomatoes throughout the western states. These lines suffer minimal curly top losses, even in areas of severe exposure where no leafhopper control measures are used.

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