

# Verticillium Wilt Resistance

strawberries resistant to verticillium wilt also show resistance to powdery mildew in plant disease studies

Stephen Wilhelm

**Resistance** to the Verticillium disease of strawberry occurs in a few varieties such as Sierra, Blakemore, and Marshall, in some breeding stocks, and in some forms of *Fragaria chiloensis*, one of the progenitors of the present-day large-fruited strawberry.

Resistance and susceptibility to Verticillium wilt in strawberry appear to intergrade with each other quantitatively. The Lassen variety, for instance, is completely susceptible; Shasta, slightly resistant; Marshall—Banner—moderately resistant; and Sierra, highly resistant. The capacity to express a character in this manner is often markedly displayed by octoploid—eight sets of chromosomes—plants, such as the strawberries under discussion.

*Fragaria chiloensis*, the strawberry species endemic to the Pacific Coastal region of North and South America—Chile to Alaska—appears to show among its many forms an intergradation of susceptibility and resistance to Verticillium wilt similar to that exhibited by varieties of the cultivated strawberry. Seedlings of a selection from Ambato, Peru, for instance, and clones from various localities along the Pacific Coast of California have shown varying degrees of susceptibility to wilt, but individuals from near Bodega Bay have tested highly resistant.

The accurate distinguishing in the field of Verticillium resistant from susceptible plants in seedling populations has presented many difficulties. Rarely are field conditions such that all susceptible plants succumb. Other diseases, and even soil-borne insects, usually complicate the tests. A greenhouse method employing a series of direct root inoculations has provided an accurate and rapid method of detecting susceptible plants. For this testing, the Verticillium inoculum in pure culture is transferred only by single spores, and from the resulting colonies, types are selected which have a known high level of virulence.

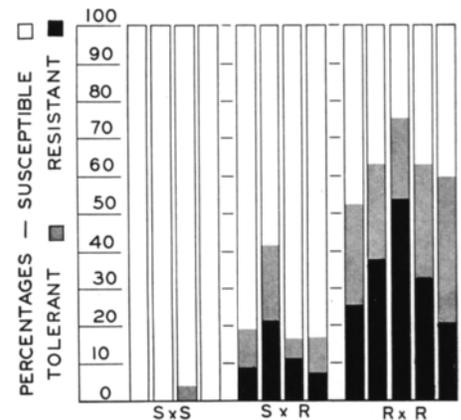
The soil mixture is exceedingly important. For a severe reaction to Verticillium, maintenance of a uniform and high level of nitrogen is essential. This may be obtained by using a partially sterilized soil mixture patterned after the U. C. mix, containing hoof and horn grist—which decomposes slowly—as a nitrogen source.

Fluctuating climate from overcast and cool to bright and warm, such as commonly occurs in Berkeley in spring, is ideal for symptom expression and makes detection of susceptible plants possible within a few weeks.

Based upon the rapidity and severity of the disease reaction, seedlings are grouped into Verticillium susceptible, tolerant, and resistant classes. Susceptible and tolerant classes manifest degrees of symptoms. Resistant plants remain entirely disease free.

## Results of Crosses

Crosses of two highly Verticillium susceptible parents have yielded primarily susceptible progenies. Occasionally plants showing a degree of resistance appear in the progenies of such crosses, but thus far these have comprised less than 1% of the seedlings. Self-pollinated Lassen plants have yielded only susceptible seedlings. Crosses of susceptible with resistant parents have yielded usually fewer than 20% of resistant plants. Crosses between two resistant plants and selfed resistant plants have yielded usually fewer than 50% of resistant plants. In the crosses studied thus far, there was the tendency for Verticillium infectable plants—the susceptible and tolerant classes—to exceed numerically the resist-



Percentages of Verticillium-susceptible—white columns; Verticillium-tolerant—gray columns; and Verticillium-resistant—black columns—strawberry plants occurring in progenies of crosses between susceptible parents—S x S—susceptible and resistant parents—S x R—and resistant parents—R x R. More than 2,300 seedlings were tested in this study.

ant plants. However, the fact that among the progenies of highly resistant parents there were susceptible plants strongly suggests that, genetically, Verticillium wilt resistance is dominant over susceptibility.

Seedlings selected as Verticillium resistant in the greenhouse tests have, with few exceptions, survived field tests of two

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**Strawberry seedlings six weeks after inoculation with the Verticillium wilt fungus by dipping the washed roots into a virulent spore suspension. The four rows to the left show resistance; the four rows to the right show susceptibility. The Verticillium-resistant seedlings—left—are also resistant to powdery mildew, while the Verticillium-susceptible seedlings—right—show severe mildew infection.**



## SHADE

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on the east and south—because vertical shade control is necessary during the morning and afternoon. Low-branching trees planted on the west and northwest would provide horizontal shade in late afternoon and early evening. Such plantings would provide good cooling shade during the entire day.

By planting deciduous trees on the east and south, the benefit of the sun could be had in winter when the trees have dropped the leaves. Evergreen trees—broadleaved or conifer—on the west or northwest would not interfere with the winter sun but would provide green foliage and protection from the winter winds.

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## MILK

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price must be high relative to a flat price to yield the same average returns. Practical considerations of public price administration preclude the use of a price considered too high—even though consistent with costs for very small volume deliveries. Such plans would probably underprice milk for small serves and, to average out, would require overpricing certain volume groups near the end of the discount bracket.

One discount schedule for wholesale sales has been arbitrarily selected for four classes with a base price of 19¢.

Arbitrary Volume Discount Schedule

Volume per delivery (labor units)	Percentage discount	Effective prices
0-74 .....	0	\$0.1900
75-224 .....	8	.1748
225-449 .....	10	.1710
450 and over .....	12	.1672

With a base price of 19¢, the schedule must fail to reflect completely the actual costs involved in servicing very small volumes per delivery, but the general nature of the price changes tends to follow costs. This type of a schedule is not very complicated nor does it involve radical departures in billing methods.

Some of the major limitations of a volume discount system which brackets several delivery volumes are made clearer in the case of retail deliveries. Costs for a one-unit retail delivery are about 28.5¢ while for two units, the unit cost is

about 5¢ lower. If, for example, one- and two-unit deliveries are bracketed at 26¢ per unit, the price would more closely reflect costs for these small deliveries than does the present uniform price system which involves a 21.5¢ price for all delivery sizes. However, there would be the obvious disadvantage of underpricing one-quart serves by 2.5¢ while overpricing the two-quart serves by slightly more than 2.5¢. Furthermore, it would provide no price incentive for one-quart customers to increase their volume per serve through a reduction in the number of deliveries or by consolidating store and home-delivered purchases.

## Reducing Costs of Distribution

Pricing plans which reflect cost differences would encourage both wholesale and retail customers—by the lower net prices—to consolidate their orders and to limit the number of distributors from which they purchase milk.

Such consolidations would increase the efficiency of the market as a whole. That increased efficiency would be reflected in lower average costs of distribution and in correspondingly lower average gross incomes for distributors. These changes would affect individual distributors according to the changes in the number and average size of their customers which, in turn, would require immediate route reorganization and would permit route consolidations to take advantage of the increased load sizes possible with larger customers.

## Wholesale Distribution

Volume pricing systems provide the customer with an incentive to limit purchases to a single distributor.

In the Los Angeles market, the existing duplication is the smallest and the average volume per customer is the largest of all California markets studied. Therefore, estimates based on the Los Angeles market conditions will be the most conservative. In this area, wholesale customers received dairy products from an average of 1.71 distributors and the average volume per delivery was 77 labor units. Under conditions where each customer is supplied by a single distributor, the average size of delivery would be increased to 132 units. On the basis of the developed cost relationships, this would mean that a 26% increase could be made in route volumes which would result in a 19% saving in unit delivery costs. This 26% increase in route volume would permit a 20% decrease in the number of routes, if it is assumed that the total volume of wholesale sales remains constant.

In other markets, such as Fresno, a complete reorganization based on one

distributor serving each customer would permit increases in load sizes of as high as 65%.

## Retail Distribution

There is no currently available data that would indicate the probable effects of a volume pricing system on the average volume per serve and therefore on the costs of retail delivery. If the average volume per customer was increased by one labor unit per serve—an increase from three to four units—that increase in average deliveries would allow an increase of 25% in route volumes at a corresponding reduction of about 20% in the number of routes operated and in the unit costs of retail delivery. In such a case, under current cost levels, the saving would amount to nearly 1¢ per quart.

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## STRAWBERRIES

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years duration in the probable presence of strains of *Verticillium* different from the one used in the greenhouse tests. They also, with few exceptions, withstood the combined inoculations of fifty different clonal lines of the *Verticillium* fungus isolated from diseased strawberries from the major strawberry growing areas of California.

## Resistance

The *Verticillium* wilt resistant strawberries obtained in these studies with few exceptions have glossy, dark green leaves and are also highly resistant to powdery mildew. Not all of the mildew resistant seedlings proved to be resistant to *Verticillium* wilt, but approximately 95% of the *Verticillium* resistant seedlings have proved to be also resistant to mildew. Since powdery mildew is a troublesome disease of strawberry in California, this may prove to be an exceedingly useful genetical linkage and may enable the plant breeder to develop a variety of strawberry completely resistant to both diseases.

There is no indication thus far in this work that any desirable qualities are lost in this rigorous selection for resistance to *Verticillium* wilt.

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*The U. C. soil mix was developed by K. F. Baker, Professor of Plant Pathology, University of California, Los Angeles, and his coworkers.*