Verticillium Wilt and Black

progress toward control made by soil fumigation with CWP-55

Soil fumigation with technical chlorobromopropene—CBP-55—offers considerable promise for control of Verticillium wilt and black root rot of strawberry.

Fumigation tests in 32-gallon cans of soil indicated that a field dosage of CBP-55 at 30 gallons per acre probably would reduce the amount of Verticillium considerably and that 45 to 60 gallons probably would eradicate it almost completely.

Since satisfactory commercial control of soil-borne plant pathogens—disease-causing organisms—is commonly achieved by a reduction in the amount of the pathogen, field tests with CBP-55 centered around the 30 gallon treatment.

Initial tests were made near Watsonville in 1949–50 on a light loam soil. A dosage of 30 gallons per acre of CBP-55 was applied in the fall by machine in two separate 15 gallons per acre treatments. The fumigant was injected 6" to 8" deep into the soil. Prior to the second application the soil was plowed. An interval of five days elapsed between the first and second fumigation. This method of split treatment is believed to insure a more uniform fumigation—especially against a fungus like Verticillium—which occurs in part in the upper few inches of soil.

This split treatment gave an excellent control of black root rot, and reduced the incidence of Verticillium wilt from greater than 65% down to 5% in an experimental, noncommercial strawberry variety. The incidence of Verticillium wilt did not increase appreciably in the fumigated plot in the second year. Plant roots from the fumigated soil were examined and cultured. The major fungus pathogens named later in the section on black root rot—with the exception of *Cylindrocarpon* spp.—were absent, as were root lesion nematodes.

More extensive tests were made in 1951. Because of the large amount of rain the fumigant had to be applied in the

Portion of experimental plot. Area fumigated wi fumigated on the left. Plants with the

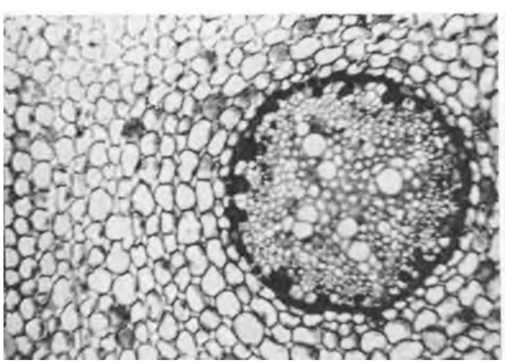
Percentage of Lassen Strawberry Plants Showing Verticillium with Symptoms Following Various Soil Fumigation Treatments

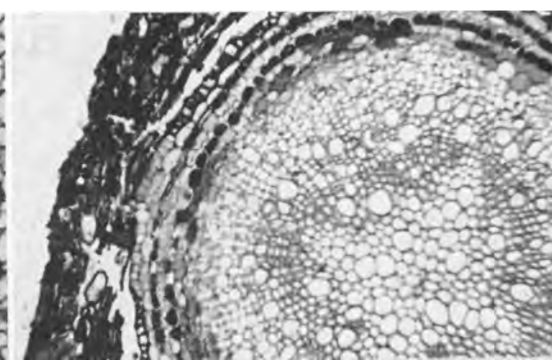
Soil treatment		Percentage of plants with Verticillium wilt*	
		Trial I	Trial II
CBP-55	30 gal./A split application*** + Shell diluent	16.0	14.5**
CBP-55	30 gal./A split application + kerosene	19.6	17.2
CBP-55	30 gal./A split application no diluent	16.5	18.9
CBP-55	30 gal./A single application	37.5	...
CBP-55	20 gal./A split application + Shell diluent	29.8	39.3
CBP-55	20 gal./A single application	43.4	43.0
DD	20 gal./A single application	57.0	75.8
DD	40 gal./A single application	54.8	59.4
DD	80 gal./A split application	42.8	32.4
Check i.e., untreated control plots		77.0	80.0

* Percentage based upon examination of 1710 plants per plot.

** Shasta planted in a portion of this plot showed 5%.

*** Half of the dosage is applied at one time. The soil is plowed after one week and then the second half of the dosage is applied.





Portions of cross sections of the large adventitious roots of Strawberry. *Left,* healthy root in the first year showing small central cylinder of wood and extensive cortex. *Right,* root in the second year showing large cylinder of wood, bark tissue and the dead cortex being sloughed off, a natural process.

Root Rot of Strawberry

in split treatments of a combined dosage of 30 gallons per acre

Stephen Wilhelm

spring, and under rather unfavorable conditions for good fumigation. Each experimental application involved approximately one-tenth of an acre. The test strawberry variety was for the most part Lassen. In checking results on the control of Verticillium wilt, approximately 1,710 plants were examined in each experimental plot. In addition a commercial treatment consisting of 15 acres was available for evaluation.

ith 30 gallons CBP-55 split is on the right, non-
outer dry leaves have Verticillium wilt.

Early in September 1951, untreated plots—left as checks—showed 75% to 80% of Verticillium wilt and extensive root deterioration from black root rot. Six Lassen plots, treated with split applications of CBP-55 at 30 gallons per acre, showed from 14.5% to 19.6% of Verticillium wilt. On the nonwilted plants in these plots, root growth appeared to be healthy, indicating apparent control of the root rot. The single application of CBP-55 at 30 gallons per acre did not give a satisfactory commercial control.

Smaller tests were made with the Shasta variety which is only slightly resistant to Verticillium wilt. A split application of 30 gallons per acre of CBP-55 gave 5% of Verticillium wilt plants. The commercial treatment in a plot planted to an unnamed moderately resistant variety showed only 3.1% and 4.4% of Verticillium wilt. Thus, the amount of control obtainable by a minimal fumigation dosage is influenced to some extent by the degree of Verticillium resistance the variety possesses.

The incidence of Verticillium wilt was also reduced by application of 40 and 80 gallons of D-D, but control was not sufficiently great to be satisfactory commercially. Considerable control of black root rot was obtained by the 40 gallons and especially by the 80 gallons per acre application of D-D.

Increased growth response in strawberry resulting from fumigation with 30 gallons CBP-55 per acre. Plant on the left is two years old, from an experimental fumigated block; plant on the right, the same age, from a nonfumigated block. Many of the deeper roots of the plant on the left were broken in digging.

Verticillium Wilt

Verticillium wilt is caused by a single fungus species *Verticillium alboatrum* which attacks numerous crop plants and a few weeds. Strawberry plants infected with Verticillium fungus wilt in midsummer and the outermost leaves die. New leaves are greatly reduced in size and plants have a flattened, stunted appearance.

Plants of a very susceptible variety—such as the Lassen—will often die in the first year. It is common for plants which are not killed to make an apparent recovery in the late summer or fall, but rarely is recovery complete.

As to varietal differences, Lassen, Donner and Cupertino are very susceptible, Shasta and Campbell are slightly resistant, and Sierra is highly resistant to Ver-

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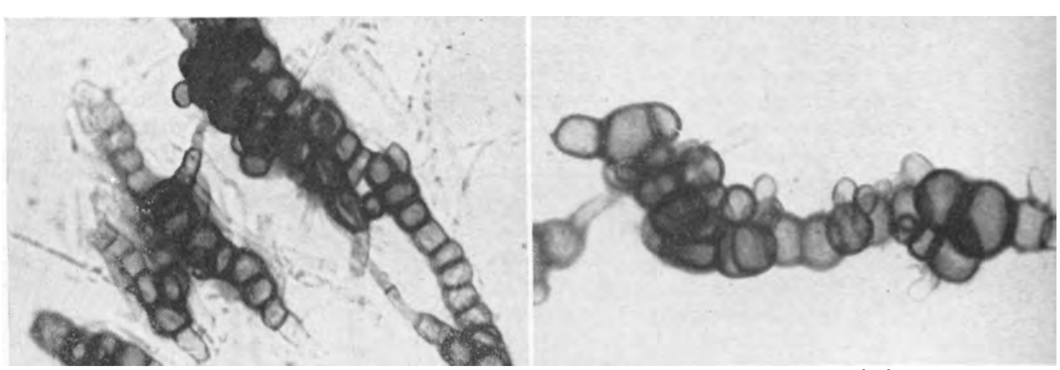

Groups of the thick-walled resting cells produced by the Verticillium wilt fungus greatly enlarged. These occur throughout roots and stems of plants after death, and thus become incorporated into the soil.

STRAWBERRY

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ticillium wilt. This holds true in most strawberry areas in California, but not in all because of strain variations in the fungus.

Infected tomato, potato, cotton and nightshade weed—*Solanum sarachoides*—are most commonly responsible for soil contamination with Verticillium. Land once infested with this fungus remains so for long periods of time, and rotations with other crops have not in general reduced the infestation significantly.

Black Root Rot

Black root rot is caused—at least in part—by a complex of soil organisms. Several different fungi, the root lesion nematode and possibly bacteria, in combination, appear to cause the roots to die.

Usually plants affected by black root rot decline sharply in their second fruiting year, rarely producing a satisfactory second year crop and almost never a third. In certain instances the plants decline rapidly during the first growing year, particularly if strawberries were grown previously on the land.

Isolations from black root rot plants have yielded many fungi. Probably significant are *Pyrenochaeta* (*Phoma*) *terrestris*—not reported previously from strawberry and known to produce a root rot of onion—*Phoma* sp. (possibly *P. radicis*) *Rhizoctonia solani*, *Pythium ultimum* *Stemphylium* sp. probably *S. radicinum*, *Fusarium oxysporum F. solani*, *Cylindrocarpon* spp. and several others, some of which are believed to be new to science.

In addition to the above fungi which grow readily in culture, microscopic examination of cleared sectioned roots revealed a great abundance of the endophytic fungus, *Rhizophogus*. Its presumed beneficial role in the nutrition of strawberry is strongly questioned.

Anatomical studies have yielded valuable information on the structure and potential longevity of the strawberry root system. The large, fleshy roots which arise from the crown are perennial in nature. In their first year they should be white until they develop vascular and cork cambiums. Healthy roots late in the first year and thereafter, add wood to the central xylem cylinder and cork to the outer bark tissues. Three layers should be distinctly visible in two years and older healthy strawberry roots, cut in cross section: *1*, the central cylinder of wood which is white; *2*, the inner bark which surrounds the wood and has the appearance of mother-of-pearl; and, *3*, the outer bark which is light to dark brown in color. If the central cylinder of wood is surrounded only by a loose punky dead bark, the root is diseased—black root rot—and the plant is on the decline. Specific information as to the natural longevity of the small lateral roots is not yet available.

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Harold E. Thomas, Director, Strawberry Institute of California; L. E. Gould, Junior Technologist, Shell Chemical Corp.; and E. C. Koch, Farm Advisor, Santa Cruz County, co-operated in the study.

The above progress report is based on Research Project No. 981.

MICROELEMENTS

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mature leaves, stem bark, stem wood, root bark, root wood, and fine roots. All parts were thoroughly cleaned, dried, and the separate portions of each plant were weighed. Similar parts of the nine plants from each treatment were combined for analysis, making seven samples to be analyzed for each of the five treatments.

The seedlings in the soil containing 300 ppm of added nickel died immediately after planting. Those planted in the soil having 150 ppm of added nickel made no new growth and died soon after planting. Plants in the soil to which 75 ppm of nickel had been added, made some growth but after 11 months their total dry weight was only approximately one tenth that of the control plants. The leaves on these plants showed some mottling which resembled that caused by a zinc deficiency. They had a lower top to root weight ratio than the controls. No root injuries were apparent. The plants grown in the soil containing 25 ppm of nickel were normal in appearance but of somewhat reduced size compared to the controls.

Similar experiments with copper additions to the soil indicate that nickel is considerably more toxic to sweet orange seedlings than copper.

The leaf samples were analyzed spectrographically. The results showed that the available nickel in the soil is readily taken up by the plants and can be detected easily in the leaves.

The presence of toxic amounts of nickel appears to lower the uptake of copper by the plant but not to the extent of producing a deficiency. The amounts of chromium found in the leaves are somewhat but not significantly increased. The amount of manganese in the leaves is not altered except when large amounts of nickel are present.

Only about 30% depression in growth was caused by the 25 ppm of nickel in the soil during this first year of growth. The ultimate effect on the mature tree is not yet known.

In only a few samples of leaves from citrus orchards has nickel been found in amounts that might be regarded with suspicion. One of these trees—containing 8 ppm of nickel—came from some trees which had received an extremely large application of sulfur to the soil. In this case the pH of the top foot of soil had been lowered to 3.3. These leaves also contained an excessive amount of manganese but it is difficult to say whether the manganese was dangerously high.

The southern California soils that have been analyzed for minor components have a nickel content of from 15 to 30 ppm. Two soils fall outside this range: the soil from the Citrus Experiment Station contains only 8 ppm, and a soil from Tulare County exceeds 100 ppm of nickel. The nickel present in the average soil will normally be in the form of very insoluble compounds, but if the soil is acidified to too high a degree the nickel will be made soluble and available to the plant. Besides nickel, other elements such as copper, manganese, and zinc may be rendered soluble in toxic concentrations by excessive soil acidification.

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The above progress report is based on Research Project No. 1025.

WEED

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The alkyl 2,4-D esters of the lower alcohols are volatile and hazardous to sensitive crops. In their place a number of low volatile esters are on the market. Two of these are the butyoxyethanol ester and the propylene glycol butyl ether ester. These esters are superior to the salts and to the lower alkyl esters in controlling perennials. They approach the acid in this property.

Trials have proved repeatedly that the low volatile esters are effective wherever used on perennials.

Successful use of soil sterilants and translocated herbicides involves complex processes and requires detailed knowledge of the systems that function. Whereas contact spraying of annuals is relatively simple, use of these more involved methods requires understanding of soil-water relations, soil-plant interrelations, plant physiology and plant biochemistry.

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The above progress report, based on Research Project No. 883, is a condensation of a paper read before the session on Herbicides of the 12th International Congress of Pure and Applied Chemistry in New York.