Citrus Seedlings

influence of fumigation and other treatments of former citrus soils

James P. Martin

Second or third plantings of young citrus trees in old groves do not grow as well as did those of the original planting or as do plantings of similar young trees on formerly noncitrus soil.

Some three years ago studies were initiated to determine whether reduced growth of citrus in old citrus soils could be demonstrated with seedlings in the greenhouse, and if so, to find causes and corrective measures.

For these studies old citrus soils were obtained from orchards where growers have difficulty in getting replants to grow satisfactorily. For comparison, soils which had never been cropped to citrus—noncitrus soils—were obtained from adjacent areas such as garden spots and walnut groves.

All tests were made in three-gallon pots, and all treatments were replicated five or more times.

Sour and sweet orange seedlings made approximately 50% to 175% more growth in the noncitrus soils than in the soils from the old orchards which had supported citrus trees 40 to 70 years. The fact that reduced growth can be demonstrated in the greenhouse with seedlings makes it possible to conduct exploratory experiments concerning causes and remedies much faster than in field experiments.

In an attempt to determine the cause or causes of this reduced growth, experiments have been set up to test out several hypotheses: One, that reduced growth is due to mineral deficiency or excesses which have gradually developed in these soils; and two, that a population of unfavorable organisms has built up.

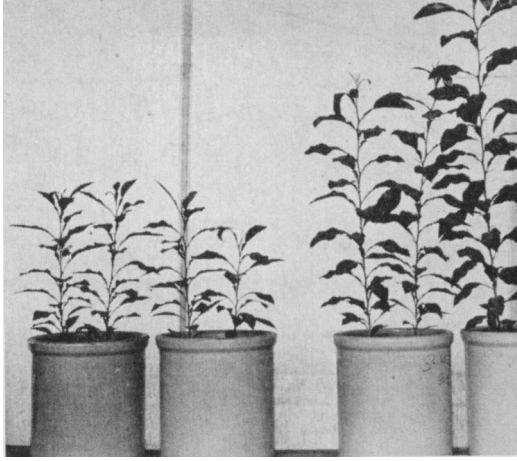
With reference to the nutritional—the first—hypothesis in the soils studied and under the conditions of these tests, seedlings in old soil did not respond to soil applications of phosphorus, potassium, magnesium, copper, boron, zinc or manganese.

These soils were very fertile as was demonstrated by tomato plants—which require relatively large amounts of plant nutrients during a relatively short growing period—which grew as well in old citrus soils as in soils virgin to citrus. In three-gallon crocks the tomato plants grew four to five feet—almost to the greenhouse ceiling.

It would be premature to regard these results as conclusive, but it would appear from this evidence and that of others that the major cause of reduced growth of orange and lemon trees in old citrus soils is brought about by other conditions.

With reference to the second hypothesis—that detrimental organisms are involved—several observations have been made.

In a detailed assay of the fungus flora of old citrus soils compared with that of noncitrus soils, several fungi were persistently found in the former and in smaller concentration or not at all in the latter. In addition, the probable importance of nematodes in this problem has been emphasized.



Sour orange seedlings in: *Left* old citrus soil. *Right* noncitrus soil from vicinity of Fullerton.

In all the greenhouse experiments citrus seedlings were planted bare root. In no case has a seedling planted in a noncitrus soil died. On the other hand many seedlings planted in old citrus soils died and had to be replanted. Examination of the roots of the seedlings which died showed almost complete decay of the roots. The roots of apparently healthy seedlings growing in old citrus soils showed evidence of considerable decay. Large numbers of fungi, primarily *Fusarium* species, and nematodes were found in these roots.

The roots of seedlings growing in noncitrus soils showed little evidence of decay, contained few fungi and no nematodes.

These observations all suggest that microörganisms are involved in the problem under consideration. Studies were therefore made to determine if possible the importance of the microbial factor.

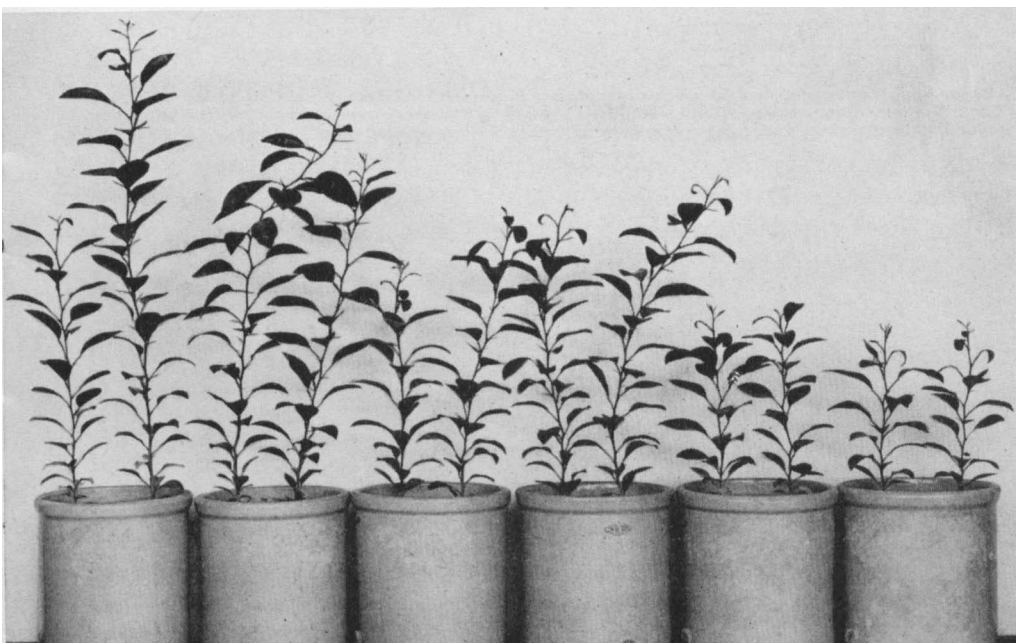
Soil Sterilization

Complete sterilization of the soil by steam—seven hours under 15 pounds pressure, calculated to destroy any detrimental microörganisms—left the soil toxic to citrus but not to tomatoes. It is possible that this treatment brought into play some organic or inorganic substance or substances which were detrimental to citrus but not to tomatoes. Because of this reaction to steam sterilization and since the use of volatile soil fumigants has come into widespread commercial use, various of these new materials were employed in subsequent work.

In every test, fumigation of old citrus soils prior to planting stimulated growth of orange seedlings. Fumigation of noncitrus soil either slightly increased or slightly decreased growth.

The fact that rather small or indifferent effects on noncitrus soils were obtained from the use of various fumigants gives

Continued on page 10



Sweet orange seedlings growing in—*two jars on left*—noncitrus soil obtained near Fullerton; *center two jars*—in fumigated old citrus soil and—*two jars on right*—in untreated old citrus soil.

KLAMATH

Continued from page 3

shiny, dark blue-green color—*Chrysolina hyperici* and *Chrysolina gemellata*—with the proviso that feeding tests be made on the following plants: Sugar beet, flax, hemp, sweetpotato, tobacco, and cotton. A coöperative project for the importation, testing and colonization of these species then was set up between the Bureau of Entomology and Plant Quarantine and the University of California.

Importations were begun in October 1944. Most of the shipments consisted of adult beetles in the estivating stage—lying dormant during the summer months—when they were shipped from the Southern Hemisphere.

The first problem encountered after the arrival of the beetles in California was to change their life cycle so it would be in accord with the seasons of the Northern Hemisphere.

By subjecting the dormant adults daily to fine sprays of water—imitating the winter rains of Australia—the beetles were brought out of their estivation and into the egg-laying stage of their life cycle, so that fertile eggs were obtained within two to three weeks after the adult beetles arrived in California.

During the first year of importation, sufficient numbers of the beetles were received to conduct the required feeding tests. These tests were completed in May, 1945, with no feeding or egg laying taking place on any of the test plants. It was found that both species of beetles would starve and die on any plant other than Klamath weed.

The larval, or immature, stages of both species feed and develop during the winter and spring months on the basal growth of the weed. Apparently, this destruction occurs at a very critical time for the plant, as it is later unable to send up seed stalks and the roots die during the following summer.

Late in the season of 1945 four colonies of the beetles were released in areas infested with Klamath weed. One of these colonies became established, but the survivors were so few that it was not possible to make recovery collections of the beetles until 1947.

At one test location in Humboldt County where the beetles were released in January of 1946, they have increased rapidly and have destroyed a continuous stand of about 20 acres of Klamath weed.

The successful establishment of these beetles in California completed the first phase of the biological control program.

The second phase, the distribution and development of colonies in each of the infested counties, is now well underway. During the winter and spring of 1947–48 some 557,000 adult beetles were released at 122 locations in 19 counties.

The third phase of the program, the actual control of Klamath weed on the range, will require millions of the beetles, and it will be several years before the present field colonies can grow to the necessary numbers. It is recommended that in the meantime growers and ranchers use the current control methods of cultivation, application of borax, and good management practices.

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The number of adults of two species of Klamath weed beetles and the number of locations at which beetles were released in 19 counties in California, 1947–48.

County	*Chrysolina hyperici*		*Chrysolina gemellata*	
	No. adults	No. locations	No. adults	No. locations
Amador	15,000	3	7,500	3
Butte	20,000	4	5,000	1
Calaveras	15,000	3	7,500	2
Del Norte	5,000	1		
El Dorado	10,000	2	7,500	2
Humboldt	70,000	14	112,500	23
Lake			2,500	1
Madera	5,000	2		
Mariposa			4,000	1
Mendocino	20,000	4	5,000	1
Nevada			7,000	2
Napa			5,000	1
Shasta	40,000	8	16,000	6
Siskiyou	35,000	7		
Sonoma	20,000	4	5,000	1
Tehama	10,000	2	11,000	3
Trinity	40,000	8	5,000	1
Tuolumne	10,000	2	7,500	3
Yuba	30,000	6	4,000	1
Total	345,000	70	212,000	52

CITRUS

Continued from page 5

further support to the view that the poor growth in old citrus soils is possibly due to a build-up of detrimental organisms.

Examination of the roots of seedlings grown in these fumigated old citrus soils showed a great reduction in the amount of root rotting and in the numbers of fungi and nematodes. These results indicate that microbial factors are at least partly responsible for reduced growth in second and third citrus plantings.

Possible Explanations

In every experiment growth of seedlings in the fumigated old citrus soils was not as great as that in untreated or fumigated noncitrus soils.

There are several possible explanations. First, it is possible that the fumigants did not kill all the detrimental organisms. Second, assuming that all were killed, it is possible that conditions in the fumigated old citrus soils are more favorable for the reëstablishment of the detrimental organisms than for their establishment in noncitrus soil. Third, some toxic material may accumulate in the soil. Such a hypothetical toxic substance could originate either from the citrus roots themselves or from organisms decomposing root excretions and dead root matérial. If the latter should be the case the cause of reduced growth would be indirectly microbial in nature; that is, although the adverse microörganisms may be killed, substances produced by their previous activity could continue to retard growth of citrus, at least for a time.

Observations

Although studies suggest that detrimental soil organisms and possibly other factors cause reduced growth of citrus trees in old soils, other and interrelated factors may be involved under field conditions.

Any condition which decreases tree vigor such as adverse climatic factors, heavy bearing, insect infestation, or insecticides might render the tree more susceptible to the activities of soil organisms. Undoubtedly several interrelated factors cause reduced growth of citrus in old citrus soils. Some of these factors are primary in nature while others are of a secondary type.

A wide range of studies are currently underway both in the field and in the greenhouse to find efficient ways and means of overcoming these unfavorable conditions.

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