# *Soil Fumigation*

## FOUND ESSENTIAL FOR

# *Maximum Strawberry Yields*

## IN SOUTHERN CALIFORNIA

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**Tests in two southern California counties resulted in similar data offering further proof of the value of soil fumigation for strawberry production. Yield increases as high as 85 per cent were reported following soil treatment. Control of plant pathogens was excellent with full-coverage injections of a mixture of 2 parts of methyl bromide and 1 part chloropicrin applied at 225 pounds per acre.**

FOLLOWING THE FIRST successful control of Verticillium wilt of strawberry by handgun application of chloropicrin in 1953, and the subsequent successful development of machine application, preplant soil fumigation became standard practice for many strawberry growers in California. One of the first areas fumigated by tractor-adapted equipment was in Los Angeles County in 1955, and other southern California growers were quick to note the advantages of soil fumigation. Where Verticillium wilt was a serious problem, 480 pounds per acre of chloropicrin applied to moist soil gave excellent control. Where Verticillium wilt was not a problem, the application of lower rates of chloropicrin, frequently down to 150 pounds per acre, resulted in improved plant growth and significantly increased yields.

More recently, other chemicals have been used in combination with chloropicrin such as the chlorinated $C_3$ hydrocarbons, particularly Telone, and methyl bromide. Methyl bromide is a very effective herbicide. Extensive studies have demonstrated that mixtures of methyl bromide and chloropicrin are more effective in controlling Verticillium wilt and weeds than is either component alone. The mixture of two-thirds methyl bromide and one-third chloropicrin has been found to be particularly effective in soil preparation for annual replanting of strawberries.

**Above:** Strawberry plant from plot fumigated with Trizone.

**Right:** Plant from plot treated with methyl bromide-chloropicrin, full coverage application.

### Los Angeles trials

During 1961 and 1962, trials were conducted in Los Angeles County to study the degree and nature of both yield and growth response in strawberries from soil fumigation. These trials also compared different fumigants and methods of application. The sites were fine sandy loam soils which had been fumigated and planted to strawberries the previous years.

The 1960–61 trial was on a winter planting of the Lassen variety, established in November 1960. Preplant soil injections of 225 pounds per acre of a 2:1 mixture of methyl bromide-chloropicrin were made to compare three methods of application. Treatments were: (1) full coverage application with chisels spaced 12 inches apart, (2) full coverage with chisels spaced 24 inches apart, and (3) application in the bed only, with two chisels 8 inches apart. All treatments were injected 6 to 8 inches deep. Full coverage treatments were tarped within 20 minutes following application, using 2 mil polyethylene sheeting. The bed treatments were tarped with 1¼ mil polyethylene simultaneous with fumigation by a rear-mounted tractor attachment. In bed treatments, approximately only one-half of the area is fumigated,

TABLE 1—EFFECT OF METHOD OF APPLICATION OF 2:1 METHYL BROMIDE-CHLOROPICRIN MIXTURE AS A SOIL FUMIGANT ON THE YIELD OF LASSEN STRAWBERRIES—WINTER PLANTING, LOS ANGELES COUNTY

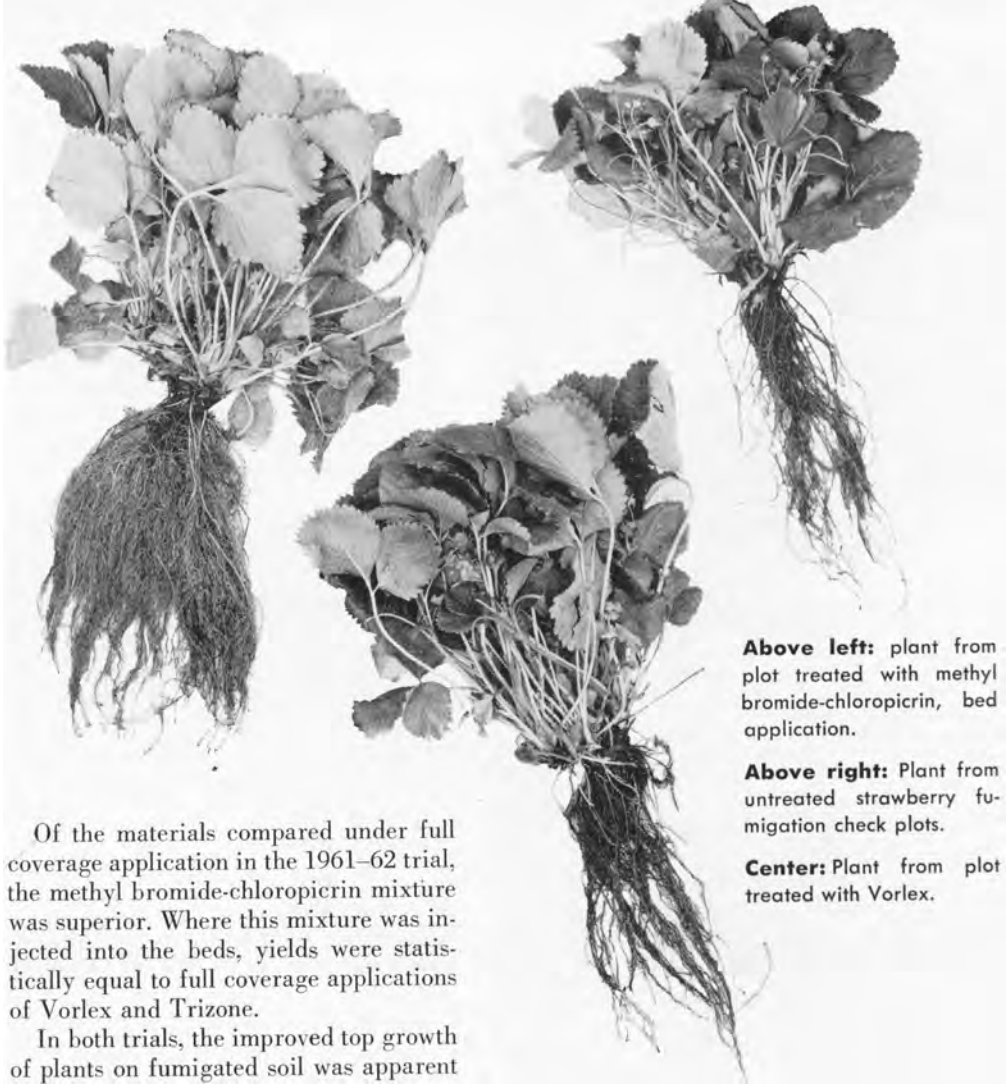
| Treatment | Number of 12-pint trays per acre (No. 1 fruit) | | | |
|---|---|---|---|---|
| | To April 7 | To May 5 | To June 5 season total | Gain* over check |
| Full coverage 12" spacing | 308 | 799 | 1,456 | 535 |
| Full coverage 24" spacing | 275 | 765 | 1,310 | 389 |
| Bed application | 273 | 724 | 1,152 | 231 |
| Check | 193 | 517 | 921 | ... |

* Increases in yield of fumigated treatments as a group over the check statistically significant at about 2 per cent level.

thus the actual rate of application per acre was 112 pounds. Tarps remained in place 24 hours. Treatment strips were 286 feet long and 4 beds (20 feet) wide, arranged in a randomized block design with each treatment replicated three times.

The 1961–62 trial was designed to compare three fumigant materials and also two methods of application of one of the materials. This trial was established on a summer planting of the Lassen variety. Soil treatments were applied in early August and plants were set in late August 1961. Treatments compared full coverage applications of methyl bromide-chloropicrin (abbreviated MB-C) at 225 pounds per acre, Vorlex (20 per cent methyl isothiocyanate, 80 per cent chlorinated $C_3$ hydrocarbons) at 30 gallons per acre, and Trizone (61 per cent methyl bromide, 31 per cent chloropicrin, and 8 per cent propargyl bromide) at 140 pounds per acre, with a bed application of methyl bromide-chloropicrin at the rate of 225 pounds per acre. In bed treatments, only one-half of the area is fumigated, thus the actual rate of application was 112 pounds. All treatments were tarped as in the 1960–61 trial, for 24 hours. Vorlex was injected with 6-inch chisel spacing, Trizone and MB-C with 12-inch chisel spacing, and the bed application with 8-inch chisel spacing (2 shanks per bed). All were injected 6 to 8 inches deep. The treatments were replicated four times in randomized complete blocks; treatment strips were each 325 feet long and 4 beds wide.

Regardless of material or method used, fumigated soil improved fruit yields significantly. Full coverage application of methyl bromide-chloropicrin in both trials was shown to be superior to bed application even though the rate of application was the same.



**Above left:** plant from plot treated with methyl bromide-chloropicrin, bed application.

**Above right:** Plant from untreated strawberry fumigation check plots.

**Center:** Plant from plot treated with Vorlex.

Of the materials compared under full coverage application in the 1961–62 trial, the methyl bromide-chloropicrin mixture was superior. Where this mixture was injected into the beds, yields were statistically equal to full coverage applications of Vorlex and Trizone.

In both trials, the improved top growth of plants on fumigated soil was apparent beginning about one month after planting. The difference in growth between plants on treated and nontreated soil was greatest at the time of peak fruit load in April. The effect of this difference in growth was reflected in significantly improved yields, beginning about the second week of production until the end of harvest.

In addition to yield increase, another striking response to soil fumigation is illustrated in the photos showing the large size of the root systems and the profusion of white rootlets as compared to plants on nonfumigated soil. This was most evident in plants from the methyl bromide-chloropicrin treatments, although a degree of improvement was seen in response to other fumigants.

TABLE 2—EFFECT OF FUMIGANTS AND TWO METHODS OF APPLICATION ON THE YIELD OF LASSEN STRAWBERRIES—SUMMER PLANTING
LOS ANGELES COUNTY

| Treatment | Number of 12-pint trays per acre (No. 1 fruit) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | To May 7 | S.S. 1% | To May 20 | S.S. 1% | To June 29 | S.S. 1% | S.S. 5% | Total gain in yield over check |
| MB-C @ 225 lbs. full coverage | 1,278 | a | 2,127 | a | 3,679 | a | a | 1,682 |
| MB-C @ 225 lbs. bed application | 1,056 | b | 1,755 | b | 2,946 | b | b | 949 |
| Trizone @ 140 lbs. full coverage | 1,042 | b | 1,723 | b | 2,885 | b | b | 888 |
| Vorlex @ 30 gals. full coverage | 941 | b | 1,581 | b | 2,523 | b | c | 526 |
| Check | 769 | c | 1,252 | c | 1,997 | c | d | ... |

S.S. = Statistical Significance. Yields followed by different letters are statistically different; those by the same letters are not statistically different.

## Laboratory studies

Root samples were obtained from the fumigation plots in October 1961, and January and June 1962 for studies in the laboratory. Rootlets were both cultured for pathogenic fungi and cleared and stained to demonstrate the presence of fungi and nematodes which cannot be grown in culture.

Roots obtained from the check plots were brown, the cortex often frayed, and the rootlets were irregularly shaped and bumpy instead of being straight. This was true of the early collections as well as the late collections. Clearing showed the rootlets to be extensively colonized by the internal fungus parasite, *Rhizophagus*, and the cortical cells invaded by *Olpidium*. These two fungi, which the authors have not succeeded in growing in culture,

One-operation fumigation of strawberry beds including application of polyethylene tarping.

may be extremely important root parasites of strawberry. Nematodes were not seen in the roots. Cultures consistently yielded *Rhizoctonia solani* (white monilioid types), and the June collection in addition yielded *Macrophomina phaseoli*, which is a destructive root parasite only at soil temperatures above 75–80° F.

Roots from the plots fumigated with Vorlex were only slightly better than those from the checks. They were distinctly brown, the cortical tissues were frayed, and many dead rootlets were present. *Rhizoctonia solani*, *Olpidium* and *Rhizophagus* were all present in abundance.

Roots from the Trizone plots were extensively developed. Rootlets were white and straight, but showed distinct areas of brown disintegration. Clearing revealed an abundance of *Olpidium* and *Rhizophagus*. *Rhizoctonia* was recovered readily in culture from the necrotic areas.

Roots from the 2:1 methyl bromide-chloropicrin plots were extensively developed, straight, white, and abundantly covered with root hairs. Clearing revealed the fungus *Rhisophagus* to be occasionally present, but failed to disclose *Olpidium*. This strongly suggests that *Olpidium* may be injurious to strawberry, and indicates it can be controlled by soil fumigation with methyl bromide-chloropicrin mixtures. *Rhizoctonia solani* also was not isolated except in the June collections. In many instances, the cultures of roots obtained from the 2:1 methyl bromide-chloropicrin plots yielded either no fungi whatsoever, or an occasional saprophytic root surface inhabitant producing only sterile brown mycelium. Laboratory results from plots receiving only bed treatments essentially paralleled those of the full coverage plots.

Growth response and high yields in strawberry following successful soil fumigation are attributed primarily to the control of injurious root-infecting fungi. The higher the level of control, the greater the plant response. The internal fungus root parasites, *Olpidium* and *Rhizophagus*, long known to inhabit strawberry roots, together with a high inoculum potential of *Rhizoctonia solani*, appear to be an injurious combination. Studies along these lines are being continued.

## Orange County trials

A test was established during July 1961 to determine the influence of certain soil fumigant materials and application methods on strawberry yields from an Orange County field. Weed control effects were also observed. Another major objective of the test was to compare bed treatment with full coverage treatment.

The area to be treated was prepared for planting and was sprinkler irrigated before application of materials so the soil would be in proper seedbed condition. The fumigants were applied on July 13 and 14, 1961, using 2 parts methyl bromide and 1 part chloropicrin at the rate of 225 lbs. per acre in two ways: (1) to raised beds prepared for later planting; (2) a full coverage over-all treatment before bedding. Bed treatments of Vorlex at 30 gallons per acre and Trizone at 150 lbs. per acre were also applied.

In the bed applications, the materials were injected into the soil about 7 inches deep, using two drill shanks per bed. These drill shanks were 10 inches apart in the bed. The machine applying the bed treatments also applied a 30-inch wide 0.5 mil polyethylene tarp that immediately covered the treated area.

The full coverage treatment was applied by injecting the fumigant 7 inches deep into the soil with the drill shanks spaced 12 inches apart. Immediately following the full coverage application, the area was covered with a 0.5 mil polyethylene tarp. In all cases, the sides of the tarp covers were tucked 4 inches deep into the soil to hold the fumigants. Nonfumigated plots were included as checks.

Treatments were replicated four times with two beds each. Two days after application, the polyethylene tarp covers were removed. Later, the non-bedded areas were listed up and all beds shaped for transplanting. Solana variety strawberry plants were set out July 29. Clear polyethylene mulch was applied to the beds on December 12, following pruning. Picking of fruit each Monday and Thursday was started on March 19, 1962. Weights of fruit from permanent sample areas in each plot were taken after each pick.

Yield data (see table 3) show that on April 30 the standard full coverage treatment of methyl bromide-chloropicrin at 225 lbs. per acre resulted in significantly better fruit yields than the other treatments at the five per cent level of significance. On May 31 and July 28, this same treatment was again superior to all other treatments and was significantly better at the one per cent level. Weed counts made August 17 from sample areas indicated that methyl bromide-chloropicrin mixtures gave best over-all weed control.

TABLE 3—EFFECT OF SOIL FUMIGANTS AND TWO METHODS OF APPLICATION ON THE YIELD OF SOLANA STRAWBERRIES—SUMMER PLANTING ORANGE COUNTY

| Treatment | Application rate per acre | Number of 12-pint trays per acre (No. 1 fruit) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | To April 30 | 5% | To May 31 | 1% | 5% | To July 28 | 1% | 5% |
| MB-Chloropicrin 2:1 full coverage | 225 lbs. | 1,083 | a | 1,994 | a | a | 2,704 | a | a |
| MB-Chloropicrin 2:1 bed | 225 lbs. | 830 | b | 1,576 | b | b | 2,153 | b | b |
| Trizone—bed | 150 lbs. | 879 | b | 1,566 | b | bc | 2,153 | b | b |
| Vorlex—bed | 30 gals. | 766 | b | 1,378 | b | bc | 1,833 | bc | c |
| Check—no treatment | | 774 | b | 1,294 | b | c | 1,736 | c | c |

Vorlex contains methyl isothiocyanate and chlorinated $C_3$ hydrocarbons.
Trizone is 61% methyl bromide, 31% chloropicrin, 8% propargyl bromide.

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