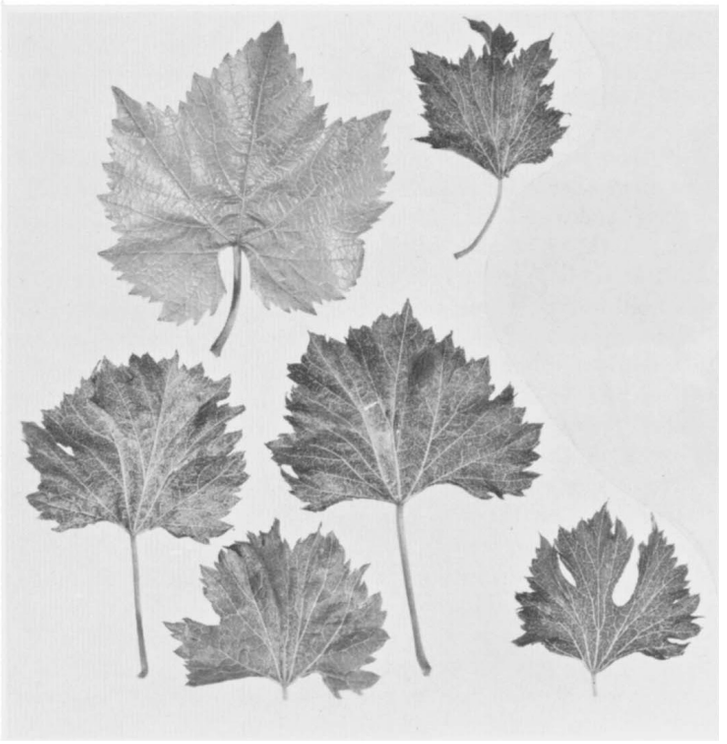
Fanleaf disease in French colombard grape vine showing deformed leaves, and cane with double nodes, and long and short internodes.



Leaves from var. Pinot Chardonnay vine. Upper left corner is a healthy leaf, all others from fanleaf diseased vine.

Controlling fanleaf virus–dagger nematode disease complex in vineyards by soil fumigation

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High-rate, deep-placement applications of the soil fumigant, 1,3-D, have been successful over a 3-year test period in controlling both the nematode vector, Xiphinema index, and the fanleaf-yellow mosaic virus disease of grapevines. A 250-gal-per-acre application rate appears to be necessary, especially on heavy soils, until results of trials with lower rates have been evaluated. Recent commercial applications of methyl bromide under continuous polyethylene sheeting indicate a good potential for control of fanleaf virus-dagger nematode disease; however, preliminary tests show that shallow applications do not give satisfactory control in the deeper layers of soil. Further tests are underway to improve the effectiveness of this material.

UNTIL RECENT YEARS there has been no practical control for fanleaf diseases and the dagger nematode vector, *Xiphinema index*, in vineyards of California. This grapevine disease complex includes fanleaf, yellow mosaic, veinbanding and enation. Each is caused by a strain of the grapevine fanleaf virus, (GFV)—which is transmitted from diseased to healthy grapevines by the dagger nematode. This nematode has been prevalent for years in the older vineyard areas of the coastal and central valley areas of the state. Virus infection on the grapevine, plus nematode damage to the root system, drastically reduces plant vigor and productivity.

The diseases may be prevented by planting vineyards with virus disease-free grapevines in clean soil, and by replanting diseased vineyards only after a long fallow period of more than ten years—or after effective chemical soil treatment so that roots of grapevines and dagger nematode vectors in the soil are killed. Early fumigation tests were ineffective, however, and fallow-rotation also was found to be impractical because of the long persistence of infectivity of soil when fallowed after the grapevines were removed.

Effective treatments to control the nematode and to kill grapevine roots to depths of some 12 to 14 feet in soils are urgently needed for successful replanting of vineyards. The first of several trials toward these goals was made in an infested vineyard near St. Helena in 1963 using deep-placement of massive dosages of 1,3-dichloropropene (1,3-D). The objective was to eliminate not only the nematode vector, but also the old grape roots left in the ground which serve as a reservoir of the virus. In these tests, 1,3-D was applied at depths of 30 to 36 inches on 18-inch centers at rates of 100 and 200 gallons per acre. Within 24 hours (in some

cases simultaneously) 50 gal per acre of 1,3-D was injected at the 8 to 10-inch depth on 12-inch centers on top of the deep placement.

The vines in block 19 were removed in 1959, and the field has remained fallow ever since except for winter barley grown in 1959 and 1960. Representative yearly data on the presence of *X. index* are shown in table 1. In early September 1970 this field was prepared by deep chiseling in two directions followed by harrowing, then on September 17 half was fumigated with 1,3-D at 250 gal per acre as described. Plantings of indicator vines are being made this spring, 1971.

The nematode counts dropped rapidly during the first three to five years after the vines were removed. This correlated closely with the decline in percentage of recoverable roots still alive in the soil. The vigor of surviving roots was determined by an iodine test for presence of starch, production of callus and/or the growth of new rootlets from root pieces stored in polyethylene bags. The presence of GFV in the roots was determined in the usual way by inoculating sap from new rootlets onto herbaceous virus indicator host plants in a greenhouse. The last year GFV was recovered from living roots dug from the test plot area was in 1964. After that date the nematodes persisted in very low and slowly declining numbers except for 1966.

The high numbers shown in table 1 came from only one of 15 sites and were recovered from only the 6-, 7- and 8-foot depths. There is no apparent explanation for the appearance of such high numbers at that one site. However, since soil samples were usually taken at different places within the area each year, this sample might have been taken at a location where grapevine roots were still living. The incidence of nematodes at other sites from 1965 through 1967 was similar: small numbers fairly widely scattered through the field. From 1968 through 1970 the counts were even further reduced (a total of two, two and one specimens from all the samples in 1968, 1969, and 1970 respectively), and the nematodes were recovered from the south edge of the field only.

The results indicate that recoverable roots with demonstrable virus infection may be eliminated in four to five years. However, the results leave unanswered the question of how long beyond five years a significant virus source may persist in an undetected small number of roots which are still alive. Survival of nematodes, even in small numbers, for ten years after the host grapevines were removed suggests that soil fumigation would be advisable before planting new vines even after a prolonged rotation.

The first trial using deep placement of high dosages of 1,3-D was made in 1963 in two blocks at St. Helena where the fanleaf-diseased vines had been removed one year previous to the treatment. Four treatments were made, 1,3-D at 200 + 50 gal per acre; 1,3-D at 100 + 50 gal per acre; CS_2 at 300 gal per acre; and an untreated control. Each treatment was replicated four times in 32 by 100 ft strips and randomized in each of the four blocks. The fumigants were applied in late August and early September, 1963.

The CS_2 treatment was made at an 8 inch depth; the 1,3-D was applied at a 30 inch depth on 18 inch centers for the deep placement of the 100- or 200-gallon dosage; and at an 8 to 10-inch depth on 12 inch centers for the shallow application of the 50-gallon dosage.

Vitis rupestris St. George, a common rootstock, is susceptible to infection with GFV transmitted by the dagger nematode. The leaves show characteristic symptoms when plants are infected with any of the fanleaf virus strains. St. George plants, therefore are good indicators of the infectivity of soils. St. George vines were planted in the spring of 1964 at 8 by 8 ft spacing.

Nematode counts were made in both blocks in 1964 and in block 18 in 1965 and 1966. Table 2 gives a resume of the counts for block 18. Adequate sampling for nematodes was extremely difficult because of the rocky nature of the soil, especially in block 40 where sampling below 5 ft was impossible. However, in block 40, control to the depths achieved in sampling was excellent. In block 18 the initial effect was good except for some surviving nematodes taken in samples at the 8 to 12 ft depth. Reinfections were found in 1966 at 0 to 5 ft in the CS_2 plots and the plots with 100 + 50 gallons of 1,3-D. In contrast, continued good nematode control was maintained at the 200 + 50 gallons rate of 1,3-D.

Table 3 shows the incidence of fanleaf-diseased St. George plants in the treatment plots in blocks 18 and 40. Test plants became infected in the control and in the plot treated with 1,3-D at 100 + 50, but not in the plots treated with 1,3-D at 200 + 50 or with CS_2. Even though test plants did not become diseased in the CS_2-treated plots, their reinfestation with dagger nematodes in block 18 showed the

Equipment for deep placement of soil fumigants (photos to right), showing applications in Napa County. Close-up photo shows detail of land wheel and shoe for deep placement delivery of soil fumigant.

TABLE 1. AVERAGE COUNTS OF XIPHINEMA INDEX IN 400 CC OF SOIL FROM FALLOW-ROTATION TEST—ST. HELENA, CALIFORNIA (BLOCK 19)

Sampling depth	Average nematode counts						
cm	1960	1962	1964	1966	1967	1968	1970
30	0.2	0.6	0.1	0.7	0.1	0	0
60	3.8	2.7	0.5	0	0.3	0	0
90	2.0	3.3	0.5	. 0	0.2	0.1	0.1
120	6.4	4.8	0.5	0.6	0.2	0	0
150	12.5	4.8	0.3	0.2	0.3	0	0
180	8.5	4.8	1.4	0.8	0.3	0.1	0
210	6.0	1.5	1.5	3.5	0.6	0	0
240	9.2	3.0	1.2	9.3	0.3	0	0
Average	5.5	3.1	0.6	1.8	0.3	0.03	0.02
No. of Sites free of X. index	2/15	1/15	8/15	11/15	5/12	11/12	8/9

TABLE 2. AVERAGE COUNTS OF X. INDEX IN 400 CC OF SOIL FROM DEEP-PLACEMENT FUMIGATION TEST—ST. HELENA, CALIFORNIA (BLOCK 18)

Sampling depth cm	1964 ck	1964 1,3-D 100+50	1964 CS_2	1964 1,3-D 200+50	1965 ck	1965 1,3-D 100+50	1965 CS_2	1965 1,3-D 200+50	1966 ck	1966 1,3-D 100+50	1966 CS_2	1966 1,3-D 200+50
	Average nematode counts											
30	0.8	0.3	0.5	0	3.8	0	0	0.3	3.3	0.3	0.8	0
60	4.3	0	0	0	5.3	0	0	0	4.0	2.3	1.3	0
90	14.8	0	0	0	4.0	0.3	0	0	4.5	1.3	0.8	0
120	15.3	0	0	0	5.8	0	0	0	8.0	0.8	0	0
150	11.7	0	0	0	4.0	0	0	0	1.0	0	1.0	–
180	4.7	0	0	0	11.3	0	0	0	4.0	–	–	–
210	7.0	0	0	0	3.0	0	0	0	1.0	–	–	–
240	11.0	6.3	0	0	0	0	0	0	19.0	–	–	–
270	14.0	1.0	0	0	–	–	–	–	–	–	–	–
300	17.0	0	0	0.5	–	–	–	–	–	–	–	–
330	19.0	0	0	6.5	–	–	–	–	–	–	–	–
360	3.0	0	0	7.0	–	–	–	–	–	–	–	–
390	–	0	0	0	–	–	–	–	–	–	–	–
420	–	0	–	0	–	–	–	–	–	–	–	–

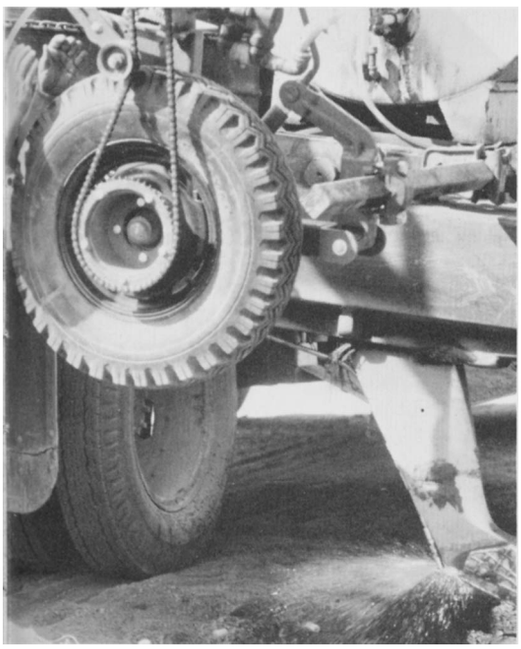
TABLE 3. INCIDENCE OF VIRUS SYMPTOMS IN 20 PLANTS PER BLOCK. DEEP-PLACEMENT FUMIGATION TEST—ST. HELENA (BLOCKS 18 AND 40)

	Application rate	Block Replicate 1	2	3	4	Total
Block 18		No. affected plants				
1965	Control	5	0	5	13	23
	1,3-D 100+50	0	0	0	0	0
	CS_2	0	0	0	0	0
	1,3-D 200+50	0	0	0	0	0
1966	Control	12	0	12	16	40
	1,3-D 100+50	1	3	3	0	7
	CS_2	0	0	0	0	0
	1,3-D 200+50	0	0	0	0	0
Block 40						
1966	Control	0	1	1	3	5
	1,3-D 100+50	0	0	0	0	0
	CS_2	0	0	0	0	0
	1,3-D 200+50	0	0	0	0	0
1967	Control	0	3	6	3	12
	1,3-D 100+50	0	0	0	0	0
	CS_2	0	0	0	0	0
	1,3-D 200+50	0	0	0	0	0

treatment was not satisfactory. These results were used as the basis in planning future tests.

Field trial 3 was set out in July 1967 in St. Helena in a typical nematode-virus infected planting from which the vines had been pulled earlier in the year. The intent was to treat the total 5.1 acres in blocks 45 and 46 with 250 gal per acre 1,3-D (200 at the 36 inch depth, 50 at the 8 to 10 inch depth). However, because of difficulties in calibration of equipment, part of the treated area received less fumigant delivered by the deep chisels at 36 inches. Thus one acre received only 155 gallons at this depth, another acre 165 gallons and the remaining 3.1 acres received 200 gallons. All received 50 gallons at 8 to 10 inches, making a total of 205 gallons for one acre, 215 for another and 250 for all the others.

No *X. index* were found in November 1969 in any of the soil samples taken in this block to a depth of 8 ft. St. George rootings were planted in the spring of 1968 and were budded to a *vinifera* variety in 1970. Examinations for virus symptoms are being continued.



Field trial 4 in block 47 (approximately two acres in size and adjacent to blocks 45 and 46) was fumigated in August 1969 with 250 gal per acre (200 deep and 50 shallow). Four months later soil samples showed the same complete elimination of *X. index* to a depth of 8 ft as obtained in the previous test. This block has not been planted because St. George rootings were not available in 1970.

In 1965 a 5-acre vineyard of the variety Colombard near Morgan Hill in Santa Clara County was chosen for treatment. All of the grapevines had fanleaf, yellow mosaic, and/or a complex of the diseases, and the soil was heavily infested with *X. index*.

The Colombard vines in the plot area were sprayed with a concentrated solution of the herbicide 2,4-D in October shortly after harvest, because prior experiments have indicated that it would most likely improve the effects of chemical soil treatment if the roots of the grapevines were killed to considerable depths. The spray consisted of two gallons 2,4-D solution per 100 gallons of water, applied at about 380 gal per acre. The vines were pulled in the spring of 1966, and 250 gal per acre of 1,3-D (200 at 30 inches, 50 at 8 inches) was applied in September 1966. Virus disease-free (certified) rootings of A × R #1 rootstocks were planted in the spring of 1967 and were budded with certified wood of the variety Pinot Noir in September of the same year.

The soil is Pleasanton loam with a hardpan at about 4 ft, and soil samples were taken from a 1.5 to 4 ft. For three years following treatment (1967 through 1969) soil samples were taken, and all were negative for *X. index*. Furthermore none of the grapevines in the plot had symptoms of fanleaf or any other virus disease when examined in June, 1970.

In the Santa Clara and Livermore Valley areas a number of semi-commercial trials were made at rates of 150 gal per acre of 1,3-D total (100 deep + 50 shallow) or at 200 gal per acre total (135–150 deep followed by 65–50 shallow respectively).

Soil samples to detect surviving nematodes were used in these tests as the most direct measure of effectiveness of the treatment. These showed that the lower dosage (150 gallons total) is not enough to eliminate *X. index*. The higher rate of 200 gal per acre total was effective in lighter soils but there is not sufficient evidence to judge performance in heavier soil types.

Experience with the test plots has shown that soil preparation for fumigation is extremely important. Although experiments in the use of the herbicide, 2,4-D, have shown that a rate of about 5 grams of the chemical applied to a grapevine in full foliage in late season will kill roots to depths of 9 ft, there is no measure of the effect of root killing on the longevity of the dagger nematode in soil, or on the infectivity of the soils for GFV. However, when the soil is being prepared for fumigation, the grapevines should be cut off as deep as possible to avoid suckering, and the roots should then be removed. Deep ripping should be made in two or three directions, moisture added in volume sufficient to wet only the surface, then disced and harrowed to break down larger clods and achieve seedbed condition. Rollerpacking the field following fumigation is also recommended.

The high-rate, deep-placement application of 1,3-D has been successful thus far in the control of both *X. index*, the nematode vector, and the fanleaf-yellow mosaic virus disease of grapevines. Inspections of fields following treatment for possible reappearance of diseased vines have been

carried out for three years, and observations will be made on one field for the fourth year.

The long-term effectiveness of the 200 gal per acre rate (150 + 50 or 165 + 35) still remains to be demonstrated, despite apparent success with such applications in lighter soils. More experience with the higher rate of 250 gal per acre suggests that this treatment should be used, especially on heavy soils, until the results of more trials have been evaluated.

Other current work

Methyl bromide is a satisfactory biocide for the control of many soil-borne diseases and weeds. Recent developments in the commercial application of this chemical under continuous polyethylene sheeting has suggested that this treatment may have good potential for control of the fanleaf virus-dagger nematode disease. However, preliminary tests have indicated that shallow application (4 to 6 inches) does not give satisfactory control in the deeper layers of soil. Additional trials are now underway to find ways to improve the effectiveness of this material. Trials now in progress or planned include: (1) a determination of the optimum depth to place the MBr (24 inches deep is greatly superior to 6 inches), (2) a determination of the optimum dosage needed for desired control, and (3) a determination of the effects of soil type and moisture content on dosage needed.

Soil fumigation with 1,3-D or MBr is costly—ranging from $300 to $600 per acre including application. However, it is encouraging that even though it is expensive there are practical procedures for control of this serious disease problem that are useful under field conditions.

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This work has been possible by the cooperation of many vineyardists including Christian Bros., Napa; George Guglielmo, Morgan Hill; and Karl Wente and Joseph Concannon, Livermore. The Shell Chemical Company provided the fumigants used in these experiments. Many members of the University of California Agricultural Extension Service also assisted, including W. H. Hart, Rudy Neja, John Joos and Douglas Hamilton.

Herbicides for WEED CONTROL

These studies demonstrated the effectiveness of several herbicides (preplant incorporated in furrow-irrigated fields) for the selective control of weeds in sesame. Additional trials are needed to determine the effects on yield and oil quality—as well as the early retardation in growth of sesame caused by herbicides as compared with that caused by weed competition. The use of selective herbicides offers effective, economical weed control.

SESAME (*Sesamum indicum* L.), sometimes referred to as benne, and one of the first oilseeds grown by man, belongs to the Pedaliaceae family. It has bell shaped flowers and the leaves are arranged opposite each other on the stem. There are many varieties of sesame, some with black, others with creamy white, dark red and brown seeds. It originated in Africa but today it is grown in many tropical and subtropical areas. In the United States it has been grown only in limited quantities because the shattering characteristics of the pod limited the effective mechanization of its harvest.

Nonshattering mutant

The discovery of a nonshattering (indehiscent) mutant in 1943 aroused new interest in the crop because of the possibility of complete mechanization of production. In recent years increased attention was given to the selection and development of varieties in the San Joaquin Valley.

It was also realized that effective methods of weed control would have to be developed before sesame could profitably be produced. Investigators in the southeastern states have evaluated the tolerance of sesame to numerous herbicides. However, these investigations were conducted in areas where periodic rainfall during the growing season enables the effective use of surface applied preemergence herbicides. In the arid Central San Joaquin Valley where furrow irrigation is utilized in sesame production, herbicides applied on the surface of the soil failed to provide adequate weed control.

Fresno County studies

In 1967, studies were initiated to evaluate the use of preplant-incorporated herbicides. In these early studies, herbicides widely used in cotton, soybeans and safflower were selected for evaluation. The rationale for this approach was that herbicides already registered for use in an oil crop could more easily be registered for use on sesame.

In 1968 it was believed that sesame in the San Joaquin Valley will be grown in a doublecropping system following barley or possibly other cereal grains. Therefore, barley was sown in the trials as a weed crop and some trials were established in fields following barley harvest.

Replicated trials were conducted on Panoche clay loam soil. Herbicides were applied with CO_2 constant pressure sprayers on preshaped beds. Following the application of herbicides they were incorporated into the soil to a depth of 2 to 2½ inches with power-driven rotary tillers.

Sesame, variety Baco, was planted at 2½ lbs per acre in the trials conducted prior to 1970. In the 1970 trials a semi-shattering variety, 215 was planted.

Barley was broadcast in the trial area, prior to bed shaping, as a weed crop in the 1969 and earlier trials. Mustard and Japanese millet were planted in the 1970 trial designated as Ss. Fr. 70-1 (see table 1). The second trial in 1970 was conducted in a field following barley harvest.

Stand counts, weed control and injury ratings were made in all trials, but no yield data were gathered.

In the three trials (see tables), several herbicides showed promise for the selective control of weeds in sesame when preplant incorporated. Some were found to control annual broadleaf weeds and grasses but failed to control volunteer barley. Others were found effective on annual grasses but provided erratic control of broadleaf weeds. Knowledge of the weed infestation or potential infestation is necessary to select the most effective and economical tools to use—whether mechanical or chemical—to control weeds in sesame.