



Four-year-old Thompson seedless grapevines. Above, planted in untreated soil; right, planted in 1,3-D treated soil. Wheeler Ridge area, Kern County.



SOIL FUMIGATION :

One Way to Cleanse

D. J. RASKI • N. O. JONES • J. J. KISSLER • D. A. LUVISI

In recent years there have been some exciting successes using deep-placement, high-dosage soil fumigation to produce flourishing grapevines where previous crops have failed due to nematodes. Re-planting new grapevines on their own roots in nematode infested soils can be disastrous because nematode attacks may destroy the developing root systems, restrict plant vigor, and reduce potential yields. In extreme cases young vines are stunted by nematodes and never develop sufficient vigor to produce a full crop.

Nematodes are widespread; infestations have been found in the soils of all the major grape producing areas of California. Root-knot nematode is especially severe and destructive in the central and southern parts of the San Joaquin Valley and almost every grower must contend with this problem in one planting or another.

It may seem inappropriate to talk about planting grapes at this time, when there has been a great surge in new plantings and falling grape prices; but the grape industry will be here long after this crisis is resolved — and so will the grapevines. There will always be some new plantings replacing older vineyards and every grower must be concerned with nematode damage which threatens investments in new vineyards. Soil fumigation is expensive, but it increases vigor of new plants, allows the freedom to choose any root-stock or own-rooted variety, and promotes economic returns which should pay for the cost of treatment in the first or second bearing season.

The first deep-placement, high-dosage trials were started in the Napa and Livermore valleys in 1963. Fanleaf virus transmitted by the dagger nematode, *Xiphinema index*, posed a serious threat to

grape production and stubbornly resisted all control efforts. Most conventional treatments failed, even prolonged rotation to other crops.

Conventional soil fumigation for nematode control in annual crops is carried out at rates of 20 gallons per acre of 1,3-D (mixtures of 1,3-dichloropropene and 1,2-dichloropropane sold as DD, Telone, Telone II, etc.) or 4.5 to 6 gallons per acre of ethylene dibromide (EDB). These are applied by chisels at 8- to 10-inch depths and 12-inch spacings. This is still standard for crops such as cotton, beans and tomatoes.

Similar methods, using up to 80 gallons per acre of 1,3-D have been tried before planting perennial tree and vine crops but seldom have been successful; the plants often are attacked by surviving nematodes before the end of the first growing season. Vigor declines often before the plants make their



Six-year-old grapevines, Alicante Bouchet var, in root-knot nematode infested soil. Left, in untreated soil; above, in 1,3-D treated soil. Delano, Tulare County.

Nematode-Infested Vineyard Lands

first full crop.

The first long-lasting control of both nematode vector and fanleaf virus was achieved by applications of 1,3-D at dosages up to 250 gallons per acre applied at 24- to 36-inch depths and 18- to 36-inch spacings. Vines grew with exceptional vigor and remained free of virus for five years and more. More recently practical methods of applying methyl bromide (MBr) on field scale have been developed. Methyl bromide is an excellent nematocide-biocide but is very volatile and has required a gas-tight cover to restrict loss by volatilization. This was accomplished by use of 1 mil polyethylene sheets 13 feet wide glued together as they are laid down at time of treatment to provide continuous cover over the entire treatment.

The initial success of those treatments against the *X. index*-fanleaf virus complex led to trials against

root-knot infestations in the lighter, sandy interior valley soils. Root-knot also had resisted conventional fumigation treatments because the nematodes survived to attack new plants that were not yet strongly established. Increasing dosage of 1,3-D to as high as 60 to 80 gallons per acre was to no avail.

Three experiments were set out to test deep-placement, high-dosage fumigation against root-knot nematode on grapes.

#1. In the first trial located in Tulare County near Delano a large block of old Alicante Bouchet var. grapevines was selected. Sixteen rows of vines extending through two avenues (76 and 78 vines long respectively) were pulled in 1969. The soil was prepared, then an area covering four rows wide was treated with 1,3-D at 200 gallons per acre applied at 18- to 24-inch depths on 36-inch spacing. An adjacent area of similar size was

treated with 1,3-D at 100 gallons per acre and the remaining eight rows were left untreated. Planting was made in 1970 using cuttings from Alicante Bouchet var. grapevines selected by the grower on his own property. In 1974 and 1975 two rows of each 1,3-D treatment and four check rows were treated with DBCP (1,3-dibromo-3-chloropropane sold as Nemagon, Fumazone, etc.) at approximately 2 gallons per acre active ingredient flooded on the soil in irrigation water.

#2. The second trial also was near Delano testing several dosages of 1,3-D (comparing DD and Telone) and MBr at 400 pounds per acre covered with polyethylene sheeting. Two different crop histories were included in the two areas of the trial: A) was in Emperor var. grapes in 1971; these were pulled and treated that year and planted in 1972; B) the adjacent

area had a prior history of grapes but had been planted to barley for four to five years including a crop in 1971. Canes cut from Muscat of Alexandria var. selected from the owner's vineyards were used for planting both areas.

#3. The third trial in the Wheeler Ridge area of Kern County was an 11-acre block of Cardinal var. grapevines that were pulled in 1971 and treated the same year. Variation in dosage of DD and Telone similar to trial #2 were applied as well as MBr at two rates, with and without polyethylene cover. Thompson seedless var. cuttings were used as planting stock in 1972.

HOW TO FUMIGATE SOIL

Soil preparation

An essential step in deep fumigation is to prepare the soil by ripping as deeply as possible. This must be done one year after existing trees or vines are removed and when the soil is quite dry and will fracture. Ripping must be done in at least two directions perpendicular to each other, and preferably in both diagonal directions as well. The chisels should be set at 30 to 36 inches or deeper.

Soil fumigation

1,3-D has given best control when applied first at 200 gallons per acre at 30- to 36-inch depth on 36-inch spacing. Roller-pack the soil immediately after treatment. A shallow treatment of 50 gallons per acre on 12-inch spacing 8 to 10 inches deep should be applied as soon as practical, again followed immediately by roller-packing. Allow an interval of 20 to 25 weeks between treatment and planting.

Recent results indicate the split dosage may not be necessary if the soil preparation is carried out precisely as described. Gas chromatograph measurements of 1,3-D dispersion show equally good results from a single application of 250 gallons per acre at 30 to 36 inches deep and from split application of the same total dosage.

MBr is applied 30 to 36 inches deep on 5½-foot spacing and covered with polyethylene sheeting. This requires complicated and ex-

Table 1. YIELD OF ALCANTE BOUCHET VAR. — DELANO, TULARE COUNTY — 1973/1974/1975

Preplant treatment	Postplant treatment	4th year	Average yield (tons/A) 5th year	6th year
None (check)	—	6.0	9.9	10.0
None (check)	DBCP		10.2	12.4*
100 gal/A, 1,3-D	—	12.7**	15.6*	14.5**
100 gal/A, 1,3-D	DBCP		14.1*	14.0**
200 gal/A, 1,3-D	—	13.5**	12.4	12.4*
200 gal/A, 1,3-D	DBCP		15.1	14.0**

*Significant at 5% level.
**Significant at 1% level.

Table 2. YIELD OF MUSCAT VAR. — DELANO, KERN COUNTY — 1974/1975

Treatment	1974	Average yield (tons/A) 1975
A. Previous history - grapes		
Check	4.2	5.0
50 + 50 gal/A - DD	6.9	7.9
50 + 50 gal/A - Telone	6.7	7.5
100 + 50 gal/A - DD	5.3	6.4
100 + 50 gal/A - Telone	6.5	7.6
200 + 50 gal/A - DD	5.6	8.0
200 + 50 gal/A - Telone	7.3	9.1
B. Previous history - barley		
Check	4.3	5.6
100 + 50 gal/A - Telone	8.5	11.0
200 + 50 gal/A - Telone	8.9	12.9
400# MBr under tarp	7.8	12.2
C. Adjacent block of 20 acres with similar history as (A) and treated with 200 + 50 gal/A Telone		
	6.7	10.2

Table 3. YIELD OF THOMPSON SEEDLESS VAR. — WHEELER RIDGE, KERN COUNTY — 1974/75

Treatment	1974	Average yield (tons/A) 1975
Check	5.5	3.3
50 + 50 gal/A - DD	8.9	6.4
50 + 50 gal/A - Telone	7.0	6.1
100 + 50 gal/A - DD	7.5	6.2
100 + 50 gal/A - Telone	8.6	6.5
200 + 50 gal/A - DD	10.9	6.4
200 + 50 gal/A - Telone	10.3	6.6
MBr 400# under tarp	6.2	5.5
MBr 400# uncovered	3.9	3.9
MBr 600# uncovered	7.8	5.8

pensive equipment which is available only through commercial operators. Removal and disposal of the sheeting must be done by the grower. Time interval between treatment and planting is minimal; only 5 to 7 days delay after removal of the plastic cover is necessary.

Data from recent trials indicate MBr also can be used successfully without the cover, providing the dosage is increased by 20 percent. Precise soil preparation to permit optimum depth of application is essential, as is immediate roller-packing to fill up and pack chisel marks.

RESULTS

Nematode control

In grapes, deep-placement of high dosages of 1,3-D and MBr

have controlled nematodes for four years or more. No nematode survivors were detectable by standard sampling and bioassay techniques for at least three to four years after planting. Eradication never has been achieved under field conditions; the few nematodes that escaped treatments eventually multiplied until they were readily detected.

Vine growth

One of the most notable consequences of deep-placement high-dosage treatments of soil has been the great vigor and uniform stands in new plantings. Stands of 90 to 95 percent usually are obtained at replanting.

By the end of the second growing season the vines are trained onto wire and bear heavily the

third year. Growth has been so vigorous that the shoots are extremely brittle and must be handled with extra care. Be rigorous in heavily thinning clusters to avoid stress to the young plants by over-cropping in the third and fourth growing seasons. To achieve the strongest framework possible for future production, encourage root, trunk, and cane growth.

YIELD RECORDS

Production records are available for three years, the fourth, fifth and sixth seasons after planting, in trial #1 where Alicante Bouchet var. grapevines were planted (table 1). Two years of yield records, the third and fourth years after planting, have been made in the others, trial #2 (table 2) and trial #3 (table 3). In every case the yield is based on bearing vines only.

COSTS AND BENEFITS

Cost of treatments

Since the time these tests were initiated costs of materials have increased markedly. 1,3-D now costs approximately \$3 per gallon for DD in bulk tank loads. Telone, costing \$3.90 per gallon in bulk tank loads, is being replaced by Telone II, at \$4.40 per gallon. DD contains 55 percent 1,3-D; Telone, approximately 78 percent and Telone II, 92 percent. The cost of soil preparation, application of chemical, and roller-packing afterwards must be added to the cost of the chemical.

Methyl bromide treatments, generally involving custom application, cost \$568.50 per acre for treatment of ten acres or more. This includes 400 pounds of MBr and a 1 mil polyethylene cover. Removal of the cover is the responsibility of the grower. Treatments of 500 pounds per acre without a cover, including disking and packing the soil after treatment, cost \$355 per acre.

Benefits

The average price for Alicante Bouchet in 1973 was \$119.20 per ton at the winery and \$92.50 per

ton in 1975. The increase in production on treated vines over untreated vines was worth approximately \$800 to \$900 per acre in 1973 and \$342 to \$444 per acre in 1974. (Deduction of picking costs of the additional tonnage should be included in every trial.)

Even after heavy thinning of the crop in the Muscat of Alexandria var. trial (table 2), in area B, vines in treated soil produced more than 8 tons per acre; vines in untreated soil, 4.3 tons per acre. At an average price of \$87.50 per ton, the 1974 increase was worth \$350 per acre. In area A vines in treated soil produced an average of 6.4 tons per acre; those in untreated soil, 4.2 tons per acre — an increase worth \$190 per acre.

Thompson seedless var. drew \$75 per ton at the winery in 1974. The value in increased production from vines in 1,3-D treated soils over vines in untreated soil ranged from \$113 to \$450 per acre.

Prices for 1975 were not available at the time this article was written.

Future and long-range implications

There is no doubt soil fumigation greatly benefits newly planted vines, especially under replant conditions, by helping to get uniform stands with high vigor and by producing significantly higher yields for the first two to three crops after planting than do vines in untreated soils. We must now demonstrate just how long these vines will continue to have improved vigor and production before nematodes build up and begin to weaken the vines.

Vine care is of critical importance. For one thing, plants in treated soils grow differently than those growing in untreated soils, the kinds with which most growers have had experience. Management of crop load is more difficult to achieve in treated soils. Increased vigor and cropping capacity require more careful attention to irrigation needs. At least two trials suffered obvious stress for lack of water in mid-summer even though they received normal irrigations. A sturdy vine structure will carry plants through many more years of exceptional production, despite nematodes. Avoid over-cropping and the

resulting stress which is so dangerous for young vines. Irrigation, fertilization, and pest and disease management must be optimum and timely.

Vine nutrition in treated soils needs reevaluation. Fertilizer requirements may be very different in treated soils than in soils infested with nematodes which are limiting growth of roots and vines.

Another problem that needs further study was encountered in two failures of new plantings to become properly established in fumigated soil. In both trials the variety is Zinfandel from certified sources; the vines now are three and four years old. The vines show severe nutritional deficiencies which, in one trial, are most striking in the MBr-treated area, much less so in the 1,3-D treated area. In the second trial the deficiencies are equally severe in MBr- and 1,3-D-treated areas.

In current research on this nutritional problem, rooted vines are being inoculated with mycorrhizal fungi before planting. Low populations of the fungi have been found in treated soils, high populations in and on roots of normal, healthy vines.

Grape growing in California has turned an important corner. "Virgin" lands are no longer to be found. Nematodes limit replanting, but growers have few or no alternatives. Resistant rootstocks are expensive, difficult to establish, and may be too vigorous to manage properly in good soils. Long rotations are not successful, as most if not all the alternative crops also may be hosts of root-knot.

Deep-placement of high dosages of soil fumigants can provide soils virtually free of nematodes. Growers then have the freedom to plant any variety of grapes desired. With proper care, vines should have many years of good productivity.

D. J. Raski is Nematologist and N. O. Jones is Staff Research Associate, University of California, Davis. J. J. Kissler is Farm Advisor, San Joaquin County, and D. A. Luvisi is Farm Advisor, Kern County.