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STUDIES ON THE USE OF DBCP IN VINEYARDS. I. TWO YEARS OF EFFICACY DATA

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ABSTRACT

Fluctuations in nematode population, vine vigor and yield were assessed in five commercial vineyards following implementation of 18 different nematicide treatment programs. Data from 11 treated sites indicated a 79 to 179% change in fruit yield as a result of DBCP with a two year average of 132% improvement over untreated. We calculate an average gross return of six dollars for every one dollar of DBCP input. Including application costs the average gross return was 4.7 dollars to one. Data obtained were highly variable depending upon vine and vineyard condition, and method of DBCP application. Vines with limited root systems were damaged by use of repeated DBCP applications in one vineyard. Greatest yield improvements were obtained in two treatment sites where water applications were made; however, certain of the chisel applications provided an equivalent vine response. Nematode samples indicated that chisel and water applications made to relatively large treatment sites were effective at lowering plant parasitic nematode populations to half of the initial. Populations of certain nematodes were not lowered due to several biotic and abiotic factors.

Nematode control is an important component of viticulture. Root damage by plant parasitic nematodes results in an estimated loss of 15% of vine yields (13). One of the few possibilities for postplant chemical control of nematodes has been the use of 1,2-Dibromo-3-chloropropane (DBCP). The objectives of this research are to: 1) assess the effectiveness of chemical nematode control strategies in vineyards, 2) determine the most suitable method and timing of DBCP applications and 3) develop information on the relative influence of soil and environmental factors on DBCP efficacy. A study was initiated to monitor vineyard vigor and yield as influenced by DBCP movement and nematode control over a period of six years in seven commercial vineyards. Recent data gathering on DBCP risks (2) and benefits (15) provided the stimulus for this progress report.

Information is available on DBCP movement and persistence in soil (5,6,16); however, field results in vineyards are unpredictable and inconsistent (10,11,12). The target spectrum of DBCP is relatively narrow although organisms other than nematodes may be directly and indirectly affected (14). The quantitative impact of nematodes on grapes is only vaguely understood (3). Numerous questions on economic threshold levels and the importance of each nematode species are unanswered. This study provides information on DBCP as a nematicide and on the importance of nematodes in the vineyard ecosystem. The justification for this extensive field study with its interdisciplinary aspects was to develop a broader information base than could be provided by an intensive, highly replicated study in a single field.

MATERIALS AND METHODS

Application methods: Five vineyards of different history, management, soil characteristics and location were selected. In each case nematodes were suspected to be causing some crop loss. Nematicide treatments were made in an area of the vineyard where both low and high vigor vines were present. DBCP was applied with application methods, rates and timing appropriate to the grower and topographic situation (Table 1). Previous studies on nematode distribution (4) indicated a high percentage of nematodes in the berm. Application techniques were related to this distribution to improve efficiency.

Each treatment was applied to three adjacent vine

Table 1. Schedule of rates, timings and methods of nematicide application used in five California vineyards.

Treatment	Vineyard	DBCP[a] (ai) Rate kg/ha	DBCP[a] (ai) Total /ha	Surface area treated	Timing
Water applications					
1	1	81	161	1/3 (in furrow)	S-'76, '77
2	2	81	81	Entire surface	S-'76
3a	2	40	27	1/3 (French plow furrow)	S-'76, '77
3b	5	40	81	1/2 (crowder blade)	S-'76, '77, F-'76
Chisel applications					
4	1	81	121	3/4 (drive row only)	S-'76, '77
5a	1,2,3	40	54	1/3 (berm only)	S-'76, '77, F-'75, '76
5c	4	40		1/3 (berm only)	F-'75, S-'76
		95	58		F-'76
5c	5	40		1/3 (berm only)	S-'76
		95	76		F-'76, S-'77
5b	1	61	54	1/3 (berm only)	S,F-'76
6a	1,2,3	40	161	Entire surface	F-'75, '76, S-'76, '77
6a	4	40		Entire surface	F-'75, S-'76
		95	176	Entire surface	F-'76
6a	5	40	121	Entire surface	S-'76, '77, F-'76
6b	1	81	161	Entire surface	S,F-'76
Carbofuran application					
10	4	69	22	1/2 berm area on Northside	S-'76
		67	17	1/2 berm area on Southside	S-'77

[a] 81 kg/ha = 72 lb/ac = 6 gal Fumazone 86 EC/acre.
40 kg/ha = 36 lb/ac = 3 gal Fumazone 86 EC/acre.

rows as a unit, involving 180 to 360 grape vines. Fumazone 86 EC (Dow Chem. Co., Midland, Mi.) was used in all experiments. Water applications consisted of mixing DBCP into irrigation water following a prior, quick irrigation. In making chisel applications to the berm the chemical was introduced into the soil through tubes behind three chisels spaced 15 cm apart. The chisels were back swept and delivered the chemical at 5 to 15 cm depth. They were followed by a dragchain to close the channel. Both sides of the vine row received treatments designed to control nematodes in a 100 cm strip down the vine row. The closest chisel was 2 to 15 cm from the vine trunk. In another treatment the closest chisel was 45 cm from the vine trunk, a standard commercial application except for the distance between chisels. A third treatment involved a combination of the two above. Except for applications made in November 1975, all chisel treatments were followed by 2 to 15 cm of irrigation or rainfall, within several days of application.

Carbofuran available as Furadan 10 G® (FMC, Middleport, N.Y.) was applied by granular spreader in a 180 cm strip down one side of the vine row for phylloxera (*Dactylasphaera vitifoliae* Shimer) control in one vineyard. Applications were preceded by a deep soil ripping and disking and followed by a disking.

Description of vineyards: Each vineyard situation was unique (Table 2) and there is a danger in generalizing from results without assessment of field conditions. None of the vineyards had previously received a pre- or post-plant nematicide treatment. Specific treatments used in each vineyard are listed in Table 1.

Vineyard 1: A peach orchard on unknown rootstock was removed in 1960 and planted to own-rooted Royalty grapes the following spring. Vine growth was vigorous and crop production excessive initially, but by 1968 production was declining and death of vines occurred sporadically throughout the vineyard (personal communication). Nineteen metric tons/ha were harvested in 1974 and 13 metric tons/ha in 1975. A routine nematode sample in 1972 revealed excessive root galling by root-knot nematode. A portion of this vineyard was extensively sampled in a statewide survey of nematode populations in vineyards (4). Populations of leafroller (*Desmia funeralis* Hubner) and leaf hoppers (*Erythroneura elegantula* Osborn) were excessively high in the late summers of 1974 and 1975, resulting in complete defoliation of some vines and reduction of photosynthetic capability in others. Weeds are managed by tillage and herbicide applications to the berm. Die-back (*Eutypa armeniacaea* Hansf and Carter) is prevalent in the vineyard and its symptoms are typically expressed in most of the dead vines (personal communication B. Teviotdale). Annual vine death is up to 5% of remaining vines. Prior to succumbing, the vine leaves are always red the previous fall and have had excessive crop/leaf ratios during the previous two years. The soil is a Hanford fine sandy loam with no restrictive layers but when dry there is an increase in soil strength below 60 cm. Variation in soil texture across the field surface is slight.

Vineyard 2: Own-rooted Thompson Seedless were planted ca 1935 following cotton and other row crops. The vines produced well in the third leaf but a weaker area is present in the center of the treated area. In 1973 an extensive soil sampling revealed numerous nematode characteristics of the vineyard (4). Treatments of granular nematicides and DBCP had lowered populations in adjacent areas of the vineyard without visual or yield differences (unpublished results, McKenry). Foliar arthropod pests are minimized with frequent use of pesticides. The field was relatively weed free until 1975 and 1976 when sewage sludge containing weed seeds was applied. Powdery mildew (*Uncinula necator* Burr.), bunch rot complex (17), Spanish measles (*Fomes igniarius* Kickx) and water berry (17) are persistent important problems. The soil is a Hanford sandy loam in the weaker areas and a more shallow Hesperia fine sandy loam in the more vigorous areas. Soil compaction is not a problem except from wheel traffic in the surface 60 cm of the drive row. Irrigation is by two wide furrows. French plowing of the vine rows (17) has not been practiced since 1968, except for the vines where DBCP treatment 3a was applied (See Table 1). Vineyard drive rows are chiseled to the 60 cm depth every few years to enhance water penetration.

Vineyard 3: This vineyard was planted to own-rooted Sultanas and Thompson Seedless ca 1925. It is located on an old riverbank of extremely deep soil. The vineyard was changed to sprinkler irrigation in 1972. Improved irrigation practices have improved vine yield and vigor. Insect and fungal problems are minimal; however, weeds in the berm area make difficult the use of any equipment there. The soil is a Dello loamy sand which is uniformly deep and offers little resistance to root penetration.

Vineyard 4: The vineyard was established in two portions; the better vines on the Hanford sandy loam

Table 2. Characterization of five California vineyards studied.

	Vineyards				
	1	2	3	4	5
Location	Parlier	Selma	Selma	Malaga	Livingston
Variety	Royalty	Thompson Seedless	Sultana and Thompson Seedless	Thompson Seedless	French Colombard
Planting date	1961	ca 1935	ca 1925	1945, 1950	1969
Soil texture	Sandy loam	Sandy loam	Sand	Sandy loam	Loamy sand, sand
Soil compaction	Slight, below 60 cm	Drive rows only	None	Poor area only	None
Topography[a]	5 cm fall/30 m	1.0 cm fall/30 m	Planted on contour	8 cm fall/30 m in poor area	Sloping 15 cm fall/30 m
Recurring insect pests	Leafroller, leaf hopper	Leafroller, mites OLR	Occ. leafroller	Phylloxera, mites leafroller	Occ. OLR, leafroller
Weed control	Berm herbicide	Berm herbicide	Spot treatment	Spot treatment	Spot treatment French plow
Irrigation method	Furrows	Broad furrow	Sprinkler frequent	Furrow	Furrow
Yield (m tons/ha)[b]	5 to 27	19 to 30	11 to 19	16 to 25	13 to 25
Crop size manipulation	Light pruning	Heavy pruning, thinned, girdled	Moderate pruning	Moderate pruning	Moderate pruning
Use of grapes	Wine	Cannery, wine	Wine	Raisin	Wine
Wheel traffic	Moderate	High	Low	Moderate	Moderate

[a] 2.5 cm fall/30 m – 1 inch fall/100 ft of row.
[b] 1 metric ton/ha = 2.723 tons/acre.

were planted in 1945 whereas poorer vines on the sloping compacted Hesperia fine sandy loam were planted in 1950. The grower suspected that grape phylloxera was a major factor in the weak area in the center of the vineyard in 1970. Soil samples in 1974 revealed the presence of dagger (*Xiphinema americanum* Cobb) and root-knot nematode. Phylloxera is present throughout the vineyard. Several other insect, fungal and weed pests are present. In January of 1976 and 1977, alternate drive rows were ripped with six shanks on 45 cm spacings to 60 cm deep. Half the rows were ripped each year. Carbofuran applications were made to the ripped side of the vine row and followed by disking.

Vineyard 5 : This French Colombard vineyard is own-rooted except for replacement vines which are on 1613 rootstock (17). Planted in 1969, it is part of a larger vineyard plagued by sand streaks and heavy root-knot galling is visible on the roots even where occasional Salt Creek rootstocks (17) are utilized. The sloping topography makes precision water applications labor-intensive. Previous land use was for beans and alfalfa, with one year of fallow in 1968. Typical insect, fungal and weed problems occur. The soil is loamy sand with a deep Delhi sand across the center of the treatment area. All DBCP treatments to this vineyard were preceded by the use of a crowder blade to provide a smooth surface sloping down beneath the vine so that water applications could be concentrated along the vine row.

Evaluation methods: Efficacy of nematicide treatments was assessed by six methods: 1) yield, 2) pruning weights, 3) nematode population levels, 4) aerial photography at 300 to 500 m elevation, 5) photography at 5 to 10 m elevation, 6) subjective vine capacity ratings of individual vines based on size of canes, spurs, trunk diameter, foliar canopy and coloration, and general thriftiness. The movement of DBCP in soil was monitored (8) following many of the treatments to determine reasons for successes and failures. The data from each assessment method will be published later in greater detail. This discussion will be confined to preliminary generalizations on DBCP use in vineyards.

Yield data were obtained from either of two sources. Five each of low, medium and high vigor vines were selected in October of 1975 in each treatment and yield data were gathered from these vines when possible. Pruning weights were collected from the same vines using standard pruning methods. Alternatively, grapes from the entire treated area were harvested and weighed. Nematode samples were taken in the row at 30 cm depth increments down to 120 cm and 30 cm from the vine trunk. Eight different vines, four low and four high vigor, were sampled semi-annually from each treatment. Nematode samples were never taken within three months of the previous nematicide application. Vermiform nematodes and root-knot eggs were extracted from soil and analyzed by established techniques (1). Occasional aerial photographs at 300 to 500 m and 5 to 10 m elevation recorded effects on vine growth.

RESULTS

Yield data: In 1976 yields ranged from 84 to 253% of those in the untreated checks (Table 3). Yields in 1977 varied from 71 to 291% of the checks. The two water applications provided the greatest yield increases. For the 11 treatments where yields were repeatedly collected there was an average yield improvement of 111% in 1976 and a total of 132% for 1976 and 1977. Averaging the cost of chemical and application overheads at commercial rates over all treatment methods, we calculate a monetary gain for the growers of 123% from increased grape production over a two year period. Averaging from three vineyards where annual yield data is available, the grower was returned six dollars for every one dollar of DBCP input. Most of the yield improvement, thus far, has been in the second year following initial treatment. In vineyard 3, where

Table 3. Yield and monetary improvement of vineyards as a result of various DBCP treatment programs when compared to untreated checks.

Treat-ment	Vine-yard	DBCP overhead $ Cost ha[a]	Yield (metric tons/ha)[b] 1976 Treat-ment	1976 Check	1977 Treat-ment	1977 Check	1976 and 1977 Treat-ment	1976 and 1977 Check	Direct value of treatments to grower: Yield as % of untreated	$ improvement/ ha
1	1	$181.00	13.78	5.45	19.75	13.23	33.38	18.68	179%	$1436.00
2	2	82.00	26.96	28.73	—	—	—	—	—	—
3a	2	92.00	29.22	28.73	—	—	—	—	—	—
3b	5	126.00	24.83	21.95	30.82	10.59	55.66	32.54	171	3689.00
4	1	169.00	8.41	5.45	16.39	13.23	24.80	18.68	133	504.00
5a	1	150.00	11.57	5.45	18.24	13.23	29.82	18.68	160	1075.00
5a	2	144.00	26.65	28.73	—	—	—	—	—	—
5a	3	144.00	15.40	17.77	—	—	—	—	—	—
5c	4	130.00	18.65	22.06	20.64	24.48	39.29	46.54	84	−(928.00)
5c	5	124.00	23.47	21.95	15.14	10.59	38.61	32.54	119	878.00
5b	1	102.00	8.90	5.45	20.97	13.23	29.87	18.68	160	1129.00
6a	1	257.00	5.45	5.45	9.39	13.23	14.34	18.68	79	−(680.00)
6a	2	240.00	24.57	28.73	—	—	—	—	—	—
6a	3	240.00	15.99	17.77	—	—	—	—	—	—
6c	4	248.00	20.64	22.06	25.98	24.48	46.62	46.54	100	−(275.00)
6a	5	180.00	23.53	21.95	19.47	10.59	43.00	32.54	132	1546.00
6b	1	209.00	4.96	5.45	21.02	13.23	25.98	18.68	139	594.00
10	4	84.00	17.97	22.06	24.10	24.48	42.07	46.54	90	−(576.00)
Average % change due to DBCP									132%	123%

[a] $100/ha = $40.47/acre.
[b] One metric ton/ha = 2.723 tons/acre.

yield data were not obtained, there was an observable increase in berry size of Sultana variety treated with DBCP. Visual observations in 1977 of the five vineyards including those where yield data were not collected indicated no obvious yield differences.

Pruning weights: Pruning weights (Table 4) from 1975 and 1977 in three vineyards were slightly higher from untreated vines in 1977 than in 1975. Weights from DBCP treated vines were 79 to 221% of those from the untreated vines in 1977 with an average increase of 167%. Increases of pruning weights generally correlated with increases in yield (Table 3) except in treatment 6a and 6b in vineyard 1, where vigor improvement did not result in proportional yield improvement. Weights of fruit and prunings were decreased in vineyard 4 where root growth was previously restricted by phylloxera, soil compaction and inadequate irrigation.

Visual assessment of vine vigor: Aerial photography at 300 to 500 m elevation indicated a general improvement in vine vigor in 1977 from various DBCP treatments in each of the vineyards. In vineyards 1, 3 and 5, all DBCP treated blocks increased in foliar cover and some appeared as a darker green color. In vineyard 2, treatment 2, 3 and the untreated check appeared to have more foliage than either of the vine treatments involving chisel application. In vineyard 4, all treatments applied to the better vines appeared to have more foliage than the untreated vines. In the poorer areas of vineyard 4 only treatment 6 appeared to have a slight increase in foliage. None of the nematicide treatments in vineyard 4 produced vines as vigorous as two untreated rows adjacent to the nematicide plot which unintentionally had been receiving a more optimum irrigation for the past several years. These better-irrigated vines yielded annually 130% more fruit than the untreated check. Vines treated by chisel application in vineyard 5 had a greater foliage canopy than those receiving water applications. DBCP treated vines of vineyard 3, especially the Sultana variety, had a noticeably larger foliar canopy.

Close-range photographs, 5 to 10 m above the ground and across several vineyard rows, provided the most useful visual assessments. All DBCP treated vines in vineyard 1 continued with various degrees of new shoot growth past mid-summer whereas the untreated vines stopped vegetative growth by mid-July. Excessively vigorous vines continued vegetative growth up to the time of harvest. Late vegetative growth was also characteristic of treatment 2 in vineyard 2. Based on photographs and observations made in the summer of 1977, however, the 1977 yields of treatment 1 and 3 in vineyards 1 and 5 respectively were unexpectedly high.

Table 4. Pruning weights (kg/vine) averaged from each of 15 treated and untreated vines. Pruned vines consisted of five each of high, medium and low vigor.

Treat-ment	Vine-yard	1975 Treatment	1975 Check	1975 % of check	1977 Treatment	1977 Check	1977 % of check
1	1	0.86	0.59	146%	1.5	0.68	221%
2	2	—	—	—	—	—	—
3a	2	—	—	—	—	—	—
3b	5	—	—	—	—	—	—
4	1	0.59	0.59	100	0.86	0.66	126
5a	1	0.59	0.59	100	1.3	0.68	191
5a	2	—	—	—	—	—	—
5a	3	0.50	0.55	91	1.5	0.82	183
5c	4	1.1	1.3	85	1.1	1.4	79
5c	5	—	—	—	—	—	—
5b	1	0.59	0.59	100	1.3	0.68	191
6a	1	0.55	0.59	93	1.4	0.68	206
6a	2	—	—	—	—	—	—
6a	3	0.50	0.55	91	1.4	0.82	171
6c	4	1.2	1.3	92	1.1	1.4	79
6a	5	—	—	—	—	—	—
6b	1	0.73	0.59	124	1.5	0.68	221
10	4	1.2	1.3	92	1.2	1.4	86
Average % change due to DBCP				102%			167%

Table 5. Fall nematode populations expressed as a percent of untreated.

Treat-ment	Vine-yard	Root-knot juveniles			Root-knot eggs			Dagger			Stubby root			Other		
		1975	1976	1977	1975	1976	1977	1975	1976	1977	1975	1976	1977	1975	1976	1977
1	1	402*	141	95	903	315	90	—	—	—	—	—	—	—	—	—
2	2	48	40	129	160	43	311	17	17	37	—	—	—	Ⓛ96	8	369*
3a	2	76	49	141	268	21	249	55	5	19*	—	—	—	Ⓛ81	8	74
3b	5	110	48	42	96	28	32	—	—	—	122	589	267	Ⓡ59	38	4***
4	1	111	145	221	98	411	139	—	—	—	—	—	—	—	—	—
5a	1	180	7**	65	347	6*	22	—	—	—	—	—	—	—	—	—
5a	2	102	110	86	201	202	214	19	2*	4*	—	—	—	Ⓛ70	0	95
5a	3	123	43	8***	99	14**	35	23	53	0	283	86	100	Ⓡ123	109	11***
5c	4	127	213	448	144	62	409	48	50	21***	—	—	—	Ⓟ55	120	59
5c	5	90	44	34	70	54	21	—	—	—	639	976	550	Ⓡ90	44	0***
5b	1	246	43	187	110	69	190	—	—	—	—	—	—	—	—	—
6a	1	75	16*	45	400	68	173	—	—	—	—	—	—	—	—	—
6a	2	69	66	36**	93	105	160	44	0**	6*	—	—	—	Ⓛ92	0	0
6a	3	102	116	46	41	103	324	25	6	14	238	121	1000	Ⓡ210	33	0***
6c	4	3146	596	500	237	450	568	53	23	9***	—	—	—	Ⓟ47	92	38
6a	5	81	34	4**	61	36	1***	—	—	—	579	468	325	Ⓡ98	35	0***
6b	1	244	14*	97	502	125	73	—	—	—	—	—	—	—	—	—
10	4	4757	493	1124	299	100	1194	76	63	42	—	—	—	Ⓟ34	90	77

* - P = 0.1 Ⓟ = Pin nematode.
** - P = 0.05 Ⓛ = Root lesion nematode.
*** - P = 0.01 Ⓡ = Ring nematode.

Aerial photographs provide a method of assessing DBCP response not available at ground level. At ground level, late vegetative growth, continued development of shoots through mid-spring and early season bunch counts were the only means of assessing DBCP response. Time of budbreak in the spring of 1977 was not affected by DBCP applications in any vineyard. Increased growth of suckers and water sprouts was apparent in 1977 on the DBCP treated vines of vineyards 1 and 5.

In earlier work (4) with Thompson Seedless grape, a subjective visual rating of individual vine capacity at ground level was significantly correlated with vine yield. Subjective vine capacity ratings of individual vines in this study provided variable results, especially in vineyard 1 where yield varied as much as 20 kg from 1976 to 1977. Ratings of vine capacity resulted in no consistent findings except in relation to death of individual vines and variability in yield from year to year. Capacity ratings in each treatment were averaged over a three year period (Table 6) but were a poor assessment tool relative to aerial observations and yield data. They may prove of value as more yield data are obtained.

Foliar arthropod populations were not observably altered in any of the plots, including the carbofuran treatment. Some vines in vineyard 1, infected with *Eutypa armeniacae* and appearing dead in 1976, produced new shoots on the trunk or from below ground in 1977. This response was only present where DBCP was applied in vineyard 1.

Vines in vineyard 4 treated with carbofuran appeared visually improved from 5 to 10 m elevation in mid-spring 1976, as a result of greater shoot growth. Aerial photographs taken in July of 1976 did not substantiate the response and no response was observed in the spring of 1977.

Table 6. Results of subjective vine vigor ratings based on number of buds and canes; size of vine trunk and foliar canopy and general vine thriftiness.

Treat-ment	Vine-yard	Average subjective vigor rating/vine[a] Fall 1975			Summer 1976			Summer 1977		
		Treat-ment	Check	%	Treat-ment	Check	%	Treat-ment	Check	%
1	1	5.8	6.4	90%	3.9	3.8	103%	3.7	4.1	90%
2	2	5.4	5.1	106	4.8	4.6	104	4.7	4.6	102
3a	2	5.2	5 1	102	4.8	4.6	104	4.6	4.6	100
3b	5	5.3	5.1	104	—	—	—	4.3	4.2	102
4	1	5.2	6.4	81	3.1	3.8	82	3.6	4.1	93
5a	1	6.1	6.4	95	4.4	3.8	116	4.2	4.1	102
5a	2	4.9	5.1	96	4.5	4.6	98	4.3	4.6	94
5a	3	3.8	3.5	109	2.7	2.3	117	3.5	3.7	95
5c	4	5.7	5.6	102	—	—	—	5.6	5.7	98
5c	5	5.3	5.1	104	—	—	—	4.3	4.2	102
5b	1	5.8	6.4	91	3.4	3.6	90	4.2	4.1	102
6a	1	4.9	6.4	77	2.7	3.6	71	3.5	4.1	85
6a	2	5.0	5.1	98	4.1	4.6	89	4.6	4.6	104
6a	3	3.1	3.5	89	2.8	2.3	122	3.9	3.7	105
6c	4	5.4	5.6	96	—	—	—	5.6	5.7	102
6a	5	4.6	5.1	90	—	—	—	4.0	4.2	95
6b	1	5.6	6.4	88	5.1	3.8	134	5.4	4.1	132
10	4	5.7	5.6	102	—	—	—	5.3	5.7	93
Average vine vigor rating as a % of untreated				95%			103%			100%

[a] Rating from 0 to 9 with 9 indicating that the maximum production expected for that year would be 90 lb/vine.

DBCP movement data: No DBCP movement in soil was detected from fall 1975 applications when neither rains nor irrigation followed chisel applications. Where subsequent chisel applications were followed by irrigation, limited DBCP movement up to 15 cm laterally occurred. Chisel applications of DBCP followed by an irrigation over the surface of the treatment area (vineyards 3 and 5) provided best DBCP movement at least to the 120 cm depth with lateral movement sufficient to supply DBCP throughout the berm area. Furrow irrigation as a vehicle for lateral movement of DBCP within chiseled berms resulted in vertical movement less than 60 cm in sandy loam soils. In vineyards 1, 2 and 4 DBCP monitoring data indicate that at no time were nematoxic concentrations of DBCP present at 90 and 120 cm depths. Following a chisel application to sandy soil with 15 to 20 cm sprinkler applied water (vineyard 3 in spring 1976) resulted in DBCP movement with nematoxic concentrations available at 120 to 180 cm depth but low concentrations in the upper 90 cm. DBCP applications to soils below 25°C required subsequent irrigation for movement. Irrigations one to two days after chisel application resulted in greater DBCP movement than those two to five days later, in contrast to the work of Hodges and Lear (6), and possibly related to the presence of sorptive root systems in these experiments. All DBCP concentrations calculated to be in the soil solution of these vineyard soils were much lower than those reported by Hodges with equal application rates.

Plant parasitic nematodes: Nematode distribution was naturally variable among treatment sites within the same vineyard. Following two years of various nematicide treatment programs the sampling data from fall 1977 indicated that treatments tended to reduce nematode populations but with variability depending upon nematode genera and nematicide treatment method. Populations of ring nematode were significantly reduced ($P = .05$) from the untreated in every case where DBCP was used. Populations of dagger nematode were reduced ($P = 0.10$) in five of eight treatment sites. Numbers of root-knot eggs were significantly reduced only in one site in vineyard 5 and reductions in root-knot juveniles were only significant ($P = .05$) where repeated chisel applications were made. Numbers of pin and stubby root nematodes were not significantly ($P = .10$) altered as a result of nematicide usage, although they were present in seven different treatment sites where concomitant reductions in other nematode genera occurred. Root lesion nematode was present at relatively low and inconsistent levels in three vineyards with no consistent results apparent. Field conditions, method and timing of applications influenced nematode populations qualitatively and quantitatively.

Dagger nematode was present in nine of the 18 treated sites. Initial populations ranged from 17 to 76% with an average of 40% of the untreated checks. Carbofuran was not significantly effective on dagger nematode following two spring applications to a single treatment site.

Ring nematode was present in five treated sites at population levels of 59 to 210% of respective untreated sites. By fall 1977 numbers in all treated sites had been reduced significantly ($P = .01$) to a range of 0 to 11% of the respective untreated check.

Initial population levels of stubby root and pin nematodes varied from 100 to 670% and 34 to 55% of the untreated respectively. By fall 1977 levels were 100 to 1000% of the untreated for stubby root and 38 to 77% of the untreated for pin nematode. There were no significant changes in population levels of these nematodes as a result of DBCP or carbofuran treatments.

Root-knot nematode was consistently present in each of the 23 sampling sites. Initial population levels were noticeably lower in two sites including the site of treatment 5c and the untreated check site of vineyard 4. This fact resulted in artifically high percentage values for the two other treatment sites in that vineyard. Excluding vineyard 4 the initial populations of root-knot juveniles ranged from 48 to 402% of their respective untreated checks with an average of 137% of the untreated. Initial egg populations in all but vineyard 4 ranged from 41 to 903% of their respective untreated checks with an average of 230% of the untreated. By fall 1977 levels were 82% and 136% of the untreated for second stage and egg stages respectively.

Assessments of the nematode population data from individual vines and vineyards indicate that zones of the grape root system which did not receive DBCP (i.e. treatment 4 vineyard 1 and soil below 60 cm depth in vineyards 1, 2 and 4) developed higher root-knot populations apparently as a consequence of the nematode control achieved in adjacent root zones. This DBCP, root-knot, grape root interaction is a major source of variability in the root-knot nematode data, especially for eggs but also for second stage juveniles.

DISCUSSION

Application of DBCP can result in numerous vineyard and vine responses depending on the field situation, application rates and timing (10,11,12). DBCP applications on the average, improved to varying degrees four of the five vineyards in these studies. These were average or below average in production. Grape yield and vine vigor were generally increased and nematode populations were generally lowered in the first and second years following DBCP treatment. As previously reported (7,12) DBCP can have a variable influence on field population levels depending on the nematode involved. Such variability may be a result of habitats or distribution peculiar to the species or it may involve protective or resistance mechanisms. The direct effects of nematicides upon the host root system is an additional subject worthy of future study.

Movement patterns of DBCP in soil were variable, depending upon soil conditions but especially dependent on the method, timing, placement and irrigation procedures which followed application. Data on DBCP movement and nematode control indicate that similar application methods did not provide similar responses. In this preliminary overview it is apparent from the DBCP monitoring data that numerous commercial DBCP applications may be ineffective especially if chisels are the method of application and cool soils (< 15°C) are involved. Identification of the field problem as related to nematodes or other biotic and abiotic factors is necessary if DBCP is to be used effectively. Vines with limited root systems, or those with least vigor, respond slowest to DBCP treatment. The response is quickest in medium vigor vines, and high vigor vines show intermediate response. Nematode population levels prior to application were not a useful indicator of eventual vine response. Nematode counts do indicate that improved growth may be possible if other biotic and abiotic factors are not limiting. The most apparent and consistent vineyard responses involved the Royalty grape variety, which is known to be highly susceptible to stress. The second most consistent response involved treatments to French Colombard where insufficient irrigation water in 1977, coupled with late harvest, resulted in poor yield in the untreated vines. Interestingly, an Australian report (9) reveals that spur-pruned vines respond more favorably to DBCP than cane-pruned vines. The French Colombard and Royalty varieties were spur-pruned. The adverse effects of DBCP in vineyard 4 were due in large part to the cultural difficulties in achieving effective irrigation because of poor water infiltration and excessive vineyard slope.

Uniform application of a nematicide for which movement is water mediated and toxicity is highly influenced by soil conditions is difficult in fields with variable soil conditions. Further elucidation of the conditions for optimum DBCP movement is necessary.

CONCLUSIONS

Nematicide evaluations in perennial crops necessitate long term studies. Grape yield improved slightly in the first year of DBCP treatment and to a much greater extent in the second year. Data from pruning weights were most demonstrative of the effects of DBCP. Excessive vigor was apparent where highest quantities of DBCP were applied by use of chisels. Populations of ring nematode and dagger nematode were consistently lowered by applications of DBCP. Populations of stubby root nematode and pin nematode were consistently unaffected. Fluctuations in root-knot populations varied due to numerous factors. Visual observations made at ground level were of minimal value in estimating the impact of DBCP. Visual observations at 5 to 10 m above ground level revealed differences in vine yield during these first two years. Color photography at 300 to 500 m elevation provided an indication of DBCP effects in specific vineyards on the second year. Yearly ratings of vine capacity provided no information pertinent to the impact of DBCP on vine vigor or yield.

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