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AVOCADO FUMIGATION INVESTIGATIONS

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INTRODUCTION

THE latania scale, *Aspidiotus lataniae* Sign. is the most important insect pest of the avocado in California. The means of control employed have been to spray with a petroleum oil spray or to fumigate with hydrocyanic acid gas. Spraying was found not to give very satisfactory results on the scale and oftentimes caused injury to the avocado trees. Fumigation, on the other hand, was found to give generally satisfactory scale kills and with only occasional instances of slight injury to the tree. Spraying is the only control method available, however, under certain conditions such as in the case of very large trees or where they are planted too closely to make the manipulation of tents over them a practical procedure. For the most part, the avocado trees where the latania scale is at present most abundant are in comparatively recent plantings, and consequently, the trees are not too large to prevent covering with tents. As a matter of fact, large avocado trees may be fumigated if they are not planted too closely together. It would seem desirable to include pest control as one of the requirements of the cultural methods in the future planting of the avocado.

In June, 1931, a number of avocado trees were fumigated on the Citrus Experiment Station property in Riverside to determine their susceptibility to hydrocyanic acid at that season. In past experience with the fumigation of citrus trees, June was considered certainly as early a date in the fumigation season as desirable. Tests were then continued on a few trees at later dates. Some of the tender growth was burned with the higher dosages used, but in general, the fumigation seemed practical so far as tree injury was concerned. There were no scale insects on these trees, so that other tests followed to determine the effect on insects. The first of these tests, made at Encinitas in September, 1931, showed a very high degree of control on the latania scale and no important injury to the trees. These tests were made with liquid HCN, and the dosages ranged from 18 cc. to 24 cc.

In August and September, 1931, D. F. Palmer and A. F. Kirkpatrick carried on fumigation tests using both liquid HCN and powdered calcium cyanide. These tests were also successful. A lighter weight tent (hereafter referred to as 350 sheeting) was used in these tests, and this lighter tent causes less breakage of the avocado branches, which are more brittle than those of citrus trees. A method of fumigation was also developed involving the use of powdered calcium cyanide; this might be followed by the small avocado grower who desires to do his own fumigating.

[1]Paper No. 372, University of California Citrus Experiment Station and Graduate School of Tropical Agriculture, Riverside, California.

In 1934 the Citrus Experiment Station undertook to make field fumigation tests for the purpose of furnishing information on a number of questions that had arisen from the preliminary avocado fumigation experience: (1) the difference in gas tightness between 350 sheeting and the duck or drill tents as used in citrus fumigation; (2) the diffusion and efficiency of powdered calcium cyanide, atomized liquid HCN, and vaporized HCN; (3) the season when the best results on the scales might be secured; (4) the season when the tree was most tolerant to HCN; (5) the relative efficiency of powdered calcium cyanide and vaporized HCN during successive sets in the evening.

Monthly field fumigation tests were carried on during 1934, 1935, and 1936, and the following account is intended to give the results of these tests and to answer the questions raised:

RELATIVE GAS TIGHTNESS OF 8-OUNCE DUCK AND 350 SHEETING

A series of ten experiments were conducted on form trees to determine the gas leakage through 8-ounce duck canvas (citrus fumigation tents) and 350 sheeting (avocado fumigation tents). These experiments were carried on at temperatures varying between 59° and 70° F., and a relative humidity from 80 per cent to 95 per cent. There was no wind. The vaporizer was used in all the experiments, and 8 units of 18 cc each was the charge of hydrocyanic acid applied. Two form trees were fumigated simultaneously, one covered with 8-ounce duck and the other with 350 sheeting.

TABLE I

Form-Tree Tent Fumigation. 8-Ounce Duck and 350 Sheeting. Average of Ten Experiments. Figures Represent Per Cent HCN in Air by Weight

Minutes after introduction	8-ounce duck		350 sheeting	
	Center top	Center bottom	Center top	Center bottom
1	.2854	.2848	.3037	.2956
5	.2098	.2514	.2038	.2219
10	.1356	.1547	.1309	.1334
15	.0904	.0918	.0834	.0866
25	.0440	.0519	.0281	.0313
30	.0217	.0217	.0180	.0194
35	.0157	.0192	.0101	.0112
40	.0083	.0086	.0075	.0082
Mean	.0887	.0981	.0831	.0866

Prom table 1 it is observed that the mean average concentration was from 8 to 12 per cent higher under the canvas tent than under the 350 sheeting, even though the initial concentration was slightly higher under the sheeting tent. -A few tests carried on during a slight breeze increased the differences between canvas and sheeting, the light 350 muslin sheeting tending to flap with the slightest breeze and increase the gas leakage.

A. F. Swain and R. P. Buckner (unpublished data) using form trees compared the HCN gas concentrations under citrus tents and under avocado tents. They used vaporized HCN, atomized HCN, and powdered calcium cyanide, and found the mean concentration under the 350 sheeting was approximately 10 per cent less than under the citrus tent regardless of the method by which the HCN was introduced.

THE DIFFUSION OF POWDERED CALCIUM CYANIDE, ATOMIZED LIQUID HCN, AND VAPORIZED HCN.

The field experiments were started in November, 1934, and carried on at monthly intervals up to and including December, 1935. There was an interval from January until June of 1936 when the experiments were discontinued but started again in July and continued at monthly intervals throughout the year. An average of two or more sets or throws was made during the night, each set consisting of six trees, three on which vaporized gas was used and three on which powdered calcium cyanide was applied.

Aspiration tests to determine the gas concentration under the tents were made on two trees in each set, one tree to which vaporized gas had been applied, and one to which powdered calcium cyanide was introduced. In some instances as many as six throws were made in one night, but in these cases aspirations of the gas were made only during every other set. Gas samples were drawn from the top center and bottom center of the tree at intervals from one-half to forty minutes following introduction of the hydrocyanic acid.

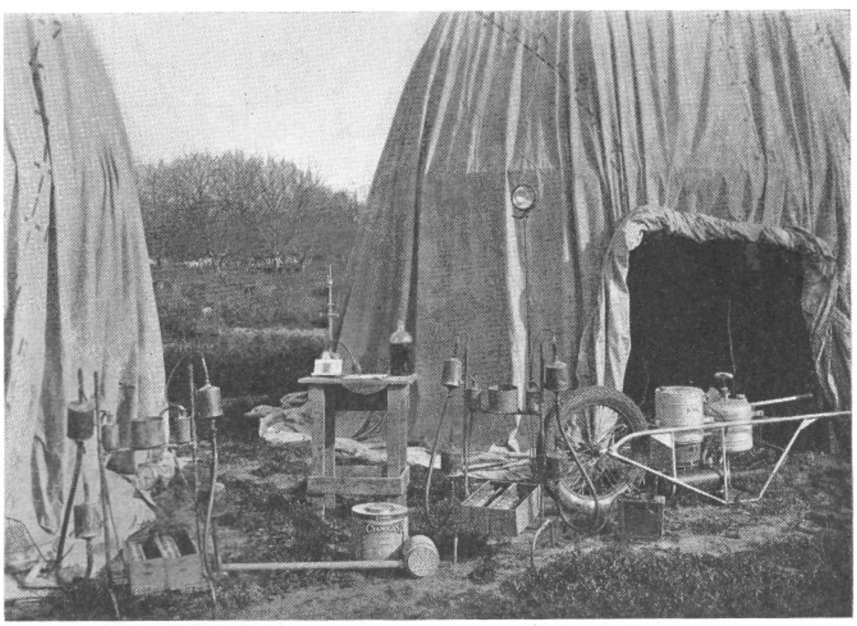
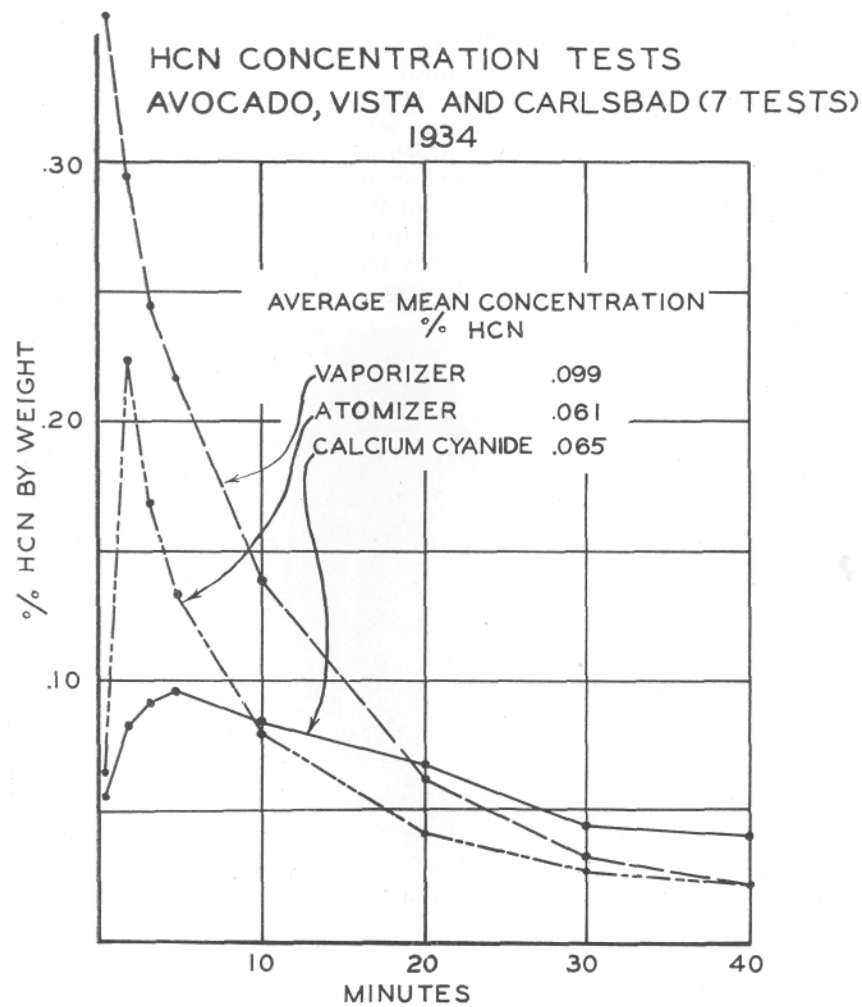


FIG. 1. Equipment used in avocado fumigation experiment.

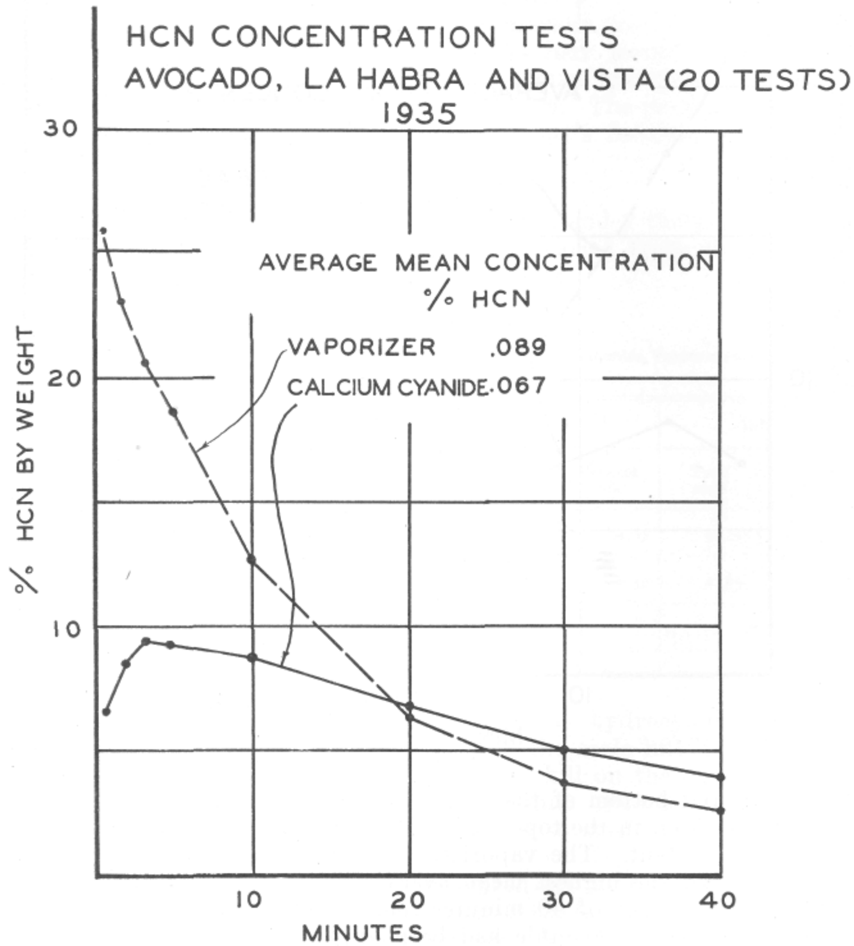
The scale infested trees were fumigated for forty-five minutes with an 18 cc schedule, or 2 ounces of powdered calcium cyanide (40-50 per cent Ca $(CN)_2$), which is approximately equivalent to 18 cc of liquid HCN. The vaporizer used in these experiments is shown in figure 1. It is the same as the one that is used in the regular citrus fumigation. The powdered calcium cyanide was applied with a shaker, which is also shown in figure 1. This consisted of a tin container, with a perforated removable cover, to which a handle was attached to facilitate shaking the calcium cyanide under the tree without exposing the operator to the dust particles.

A few tests were conducted in 1934 in which cold liquid HCN was atomized under the tent. The applicator used in these instances was the cold gas atomizer, which is used in citrus fumigation.

The gas concentration curves obtained in 1934, 1935, and 1936, are shown in graphs 1, 2, and 3, respectively. The concentrations at the top and bottom of the tent were averaged together. However, the concentration in the top in general was slightly higher than in the bottom of the tent. The vaporized gas gave the highest initial concentration and the highest mean average concentration in every case, although at the end of 40 minutes there was less gas under the tent than where calcium cyanide had been applied. In those tests where the atomizer was used, the initial concentration was higher than that received from the powdered calcium cyanide, but the mean average concentration for the 40 minutes was lower. The concentration under the tent obtained from calcium cyanide is a low, even type, and the average mean concentration is lower than the vaporized gas, indicating that in 40 minutes all the HCN had not been evolved. The only explanation offered for the lower mean average concentrations obtained in 1936 is that fewer aspirations were taken in each set, and the first aspiration was taken at one minute after the gas had been applied instead of one-half minute, as in the previous years.

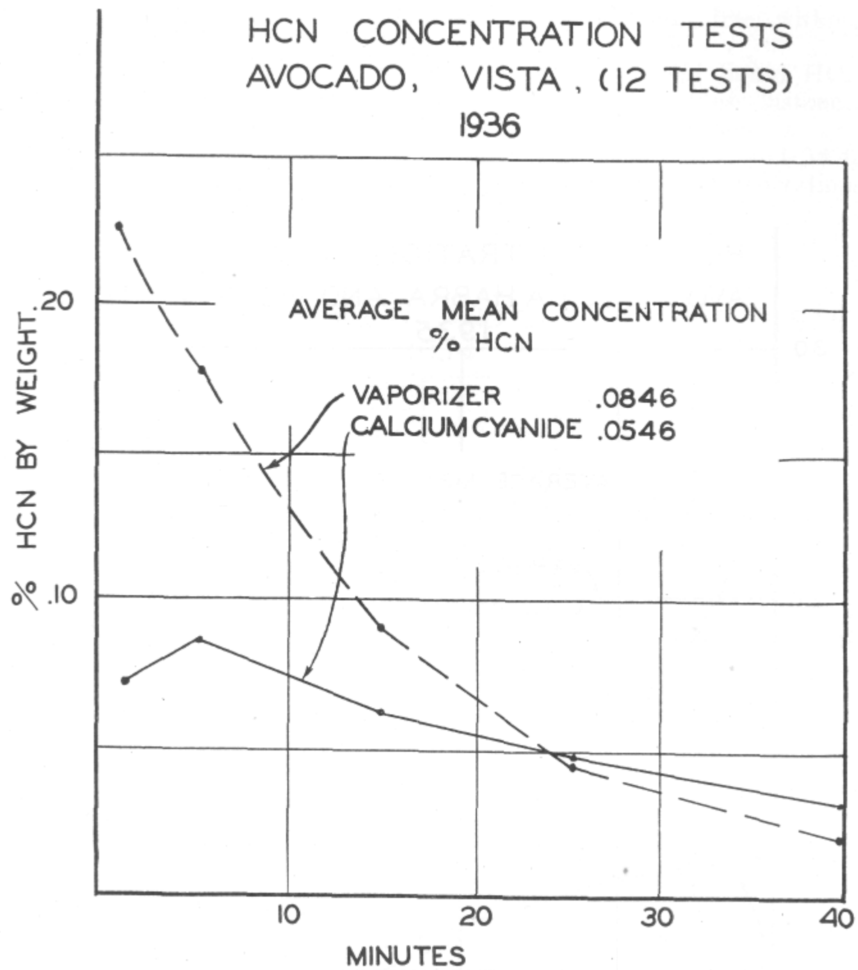


GRAPH 1.



HCN CONCENTRATION TESTS
AVOCADO, LA HABRA AND VISTA (20 TESTS)
1935
AVERAGE MEAN CONCENTRATION
% HCN
VAPORIZER .089
CALCIUM CYANIDE .067
% HCN BY WEIGHT
30
20
10
10
20
30
40
MINUTES

GRAPH 2.



GRAPH 3.

THE EFFICIENCY OF POWDERED CALCIUM CYANIDE, ATOMIZED LIQUID HCN, AND VAPORIZED HCN.

The three methods of gas application were tried side by side in 1934. Six tents were used, and two trees in each set were fumigated with calcium cyanide, atomized HCN and vaporized HCN. In 1935 and 1936 calcium cyanide and vaporized HCN only were used, since the atomized HCN method of application is being used less each year, and in time probably will be entirely replaced by the vaporizer.

$$\frac{x-y}{x}=(100)$$

Natural mortality counts were made on check trees, and the treated lots were counted approximately three to four weeks after fumigation. In table II are represented the total numbers of insects counted for each year, and each type of gas application. The per cent mortality is also shown, which was obtained by Abbott's formula, where x is the per cent alive before treatment and y the per cent alive in the treated lot. The natural mortality varied from 48 to 85 per cent depending on the grove, time of year, etc.

TABLE II

Percentage Kill of Latania Scale in 1934, 1935 and 1936. A Comparison of Calcium Cyanide, Vaporized HCN, and Atomized HCN

	1934		1935		1936	
	Total scale	Per cent kill	Total scale	Per cent kill	Total scale	Per cent kill
Calcium cyanide–Wood	12,361	89.12	52,172	94.15	44,245	99.12
–Fruit	4,142	95.46	----------	----------	----------	----------
Vaporized HCN–Wood	16,078	90.15	55,217	98.86	47,888	99.57
–Fruit	4,968	94.53	----------	----------	----------	----------
Atomized HCN–Wood	15,833	88.92	----------	----------	----------	----------
–Fruit	3,653	93.76	----------	----------	----------	----------

Regardless of the method by which the hydrocyanic acid was applied, there was very little difference in the scale kill in 1934. The vaporized gas gave about 1 per cent better kill on the wood than did calcium cyanide or atomized gas, but calcium cyanide gave the best results on the fruit. These differences are so small that they can be well within experimental error.

It is surprising that both the atomized HCN and calcium cyanide gave such good results, when the gas concentration curves for 1934 are compared (graph 1). The mean average hydrocyanic acid gas concentration for the vaporizer as shown by titration tests is .099 as compared with .061 for the atomizer and .065 for calcium cyanide.

In 1935 the vaporized hydrocyanic acid gave a better kill than did the powdered calcium cyanide. There were approximately the same number of insects counted in each series, but a kill of 98.8 per cent was obtained with the vaporized gas as compared to a kill of 94.2 per cent with the calcium cyanide, or a difference of 4.6 per cent. Here again a decided difference between the mean average gas concentration of the two types of application is noted (graph 2). The scales which had been treated with hot gas were subjected to about 25 per cent more HCN than those to which powdered calcium cyanide had been applied.

The scale kill in 1936 was very good, 99.57 per cent kill with the vaporized gas, and 99.15 per cent kill with the calcium cyanide, or very little difference between the two. Again, about as good a kill is received with calcium cyanide as with the vaporized HCN, but there is a difference in the mean average concentration under the tent, favoring the vaporizer.

The percentage kill of latania scale was not so good in 1934 as it was in 1935 or 1936. This fact in itself is difficult to explain, but still more difficult to explain when it is observed from graphs 1, 2, and 3, that in 1934 the mean average HCN gas concentration for the vaporizer was higher than for any other year. This discrepancy may be partially explained by the fewer experiments carried on during 1934 and the relatively small number of insects counted.

THE EFFECT OF THE SEASON ON FUMIGATION RESULTS.

The fumigation experiments were conducted at monthly intervals to determine the time of year when the best results on the scales might be secured. The total scale counted during each month and the percentage kill are shown in table III. So few insects were counted in the experiments carried out from January through June that these data are not included in the table.

TABLE III

Percentage Kill of Latania Scale Received During Different Months of the Year

Month	Cyanogas		Vaporized gas	
	Total scale	Per cent kill	Total scale	Per cent kill
July	15,279	99.89	16,368	99.72
August	13,268	95.61	12,682	97.93
September	8,317	99.13	12,692	99.38
October	34,860	97.08	28,330	99.80
November	20,185	96.90	24,625	99.52
December	11,837	85.60	18,584	88.00

The kill obtained from the fumigation of the latania scale was consistently high during the months of July, August, September, October, and November, with a decided reduction in kill in December. The results are similar for both calcium cyanide and vaporized HCN, but it will be noticed that the vaporized gas gave better kill in every case but one. From July through November the kill was better than 95 per cent in every case, but in December there was practically a 10 per cent reduction in the fumigation results. It may be that latania scale become harder to kill with a drop in temperature, just the reverse of the red scale *(Aonidiella aurantii)* which becomes easier to kill as the temperature is lowered (Quayle and Eohrbaugh, 1934).

TREE TOLERANCE TO FUMIGATION.

Perhaps the parts of the avocado tree most susceptible to fumigation injury are the blossoms of young fruit. The tender growth may burn but new growth rapidly appears, and the tree soon recovers. This is not so, however, in the case of the bloom and small fruit. When injured by fumigation the bloom will turn brown and die and is very easily shaken to the ground. The young fruit when injured will usually shrink, turn brown, and in a relatively short length of time, fall. It seems advisable to avoid fumigating during the bloom and until the fruit has attained approximately the size of an egg. Older fruits are only rarely injured.

THE RELATIVE EFFICIENCY OF POWDERED CALCIUM CYANIDE AND VAPORIZED HCN DURING SUCCESSIVE SETS IN THE EVENING

During the time this work was carried on it was noticed that the first set almost always gave the best results. The scale counts were therefore tabulated according to sets to determine the actual differences between the different sets. Table IV is a summary of the scale counts and percentage kills arranged according to set number. It is seen that set No. 1 is far better than any other set made. This may be due to drift gas and stupefaction, drop in temperature, an increase in relative humidity, or an interaction of all these factors combined.

TABLE IV

Percentage Kill of Latania Scale Received During Different Sets Throughout the Evening

	Set No. 1		Set No. 2		Set No. 3		Set No. 4	
	Total scale	Per cent kill	Total scale	Per cent kill	Total sclae	Per cent kill	Total scale	Per cent kill
Cyanogas	45,462	99.78	39,042	90.85	9,635	93.12	7,988	93.49
Vaporized gas	45,287	99.92	45,897	97.91	10,101	93.44	7,863	91.33

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