and gives us a much larger yield than with ground tomatoes.

In closing I would like to say that through cooperation of Mr. Kelbert and Dr. Walters of the Bradenton Experiment Station, we have learned a lot about the various varieties, and also have learned a lot more of the whys and wherefores of farming in Florida. The experiment stations can really help you if you will let them.

IN-THE-ROW APPLICATION OF SOIL FUMIGANTS FOR VEGETABLES ON SANDY SOILS

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Soil fumigation is a currently very popular subject with the vegetable growers of Florida. This is, we believe, as it should be, because our tests conducted during the past four crop seasons have shown that from our land we can expect very attractive returns for the use of the nematocides D-D or ethylene dibromide (diluted with mineral spirits and sold under different trade names).

However, our laboratory is not yet making any definite recommendations on soil fumigation with these new chemicals because we are well aware that our information on the subject is dangerously little. To illustrate how little we know about some important facets of soil fumigation, we can report that three weeks ago a regional representative of one of the big chemical companies that has been selling fumigation service in the state for the past three years stopped at the laboratory and advised us that results obtained by the company's scientists during 1949 show that water solution is the effective phase of their "fumigant." All of us had, of course, labored from the outset with the mistaken idea that the chemical produced its desirable effects while in a gaseous stage, and that, for this reason, it was proper procedure to apply it to well worked, well aerated soil and then seal the surface of the treated area by sprinkling if a quarter-inch of rain were not expected within a few hours.

Another facet of the subject that makes it appear unwise for the experiment station to issue hurried recommendations for use of fumigants is the hazard, slight though it may be, that under some unusual conditions a fumigant may result in a vegetable crop being tainted, a bit off flavor, or reduced in quality.

In-the-row application of soil fumigants has been given special attention in our tests, which were begun with the fall crop of 1947. The reasoning leading to the decision to specialize upon in-the-row application included the following considerations:

1. The available technical information and the long-time experience of growers concerning the effects of root-knot on vegetable crops appeared strongly indicative that a major share of the reduction in yields usually arises from the effects of the nematodes on seedlings or transplants during the first four or five weeks of their time in the field. In general, the radius of root spread from vegetable crop plants during the first four or five weeks would not exceed the radius of effectiveness demonstrated for 'spot' applications of the soil fumigants.

2. Many interested growers objected to the cost of the full-scale application offered as custom service by the chemical companies at rates ranging from $35 to $60 per acre. In-the-row application allows a reduction in the amount of chemical needed per acre to from 1/6 to 1/2, depending upon the between-the-row spacing of the crop under consideration.

3. It appeared reasonable that any possible accumulation of harmful chemical residues or development of unfavorable physical conditions of the soil, points on which there is, as yet, no definite information, would be minimized by limiting the amount of chemical applied per acre to the fractional quantity
called for by in-the-row application.

4. Preliminary observations suggested that use of the soil fumigant every time a given piece of land is prepared for a crop would have advantage over periodic full-scale application. In some cases root-knot was found to be very severe on the second crops grown six to nine months after full-scale treatment. Though the first crop following the treatment had been excellent, it appeared in some full-scale treated areas that the second crop suffered more severe damage than normal for similar non-fumigated areas.

The first experimental trial of in-the-row application of soil fumigant at the Vegetable Crops Laboratory was made on staked tomatoes in rows four feet apart. The materials tested were Larvacide, D-D, and Soil-fume 80-20, (ethylene dibromide 20%-mineral spirits 80%) the quantities applied on a per acre basis being one fourth the normal full-scale dosages of approximately 500 pounds, 200 pounds and 26 gallons, respectively. Applications were made with Mack guns after the beds had been prepared in the usual fashion, and the use of cultivators that could throw non-treated soil from the middles to the beds was delayed as long as possible. The plot design meant 64 replications of 10-plant plots in a test involving fungicides and insecticides as well as soil fumigants. The trial was made on land that had been used for tomatoes regularly for several years, and root-knot was known to have been almost 100 percent prevalent on the plants of the preceding crop.

The results of this first trial appeared very encouraging. Larvacide, D-D, and Soil-fume 80-20 giving increases of approximately 50, 25, and 15 bushels of marketable fruits per acre, respectively. However, the season was unusually wet, and root-knot was so slight that we do not believe it could have been a factor contributing to the yield differences noted. At the end of the harvest season five plants of each plot were lifted and rated for root-knot severity. Analysis of the numerical data showed that root-knot was more severe on plants of the non-treated check plots than on those of treated plots, there being no differences between the three chemicals in this respect.

The second experimental trial involved the same three soil fumigants but included a comparison of the dosage used in the first trial with half and double that amount. The test was made on the same field as the first, and root-knot was known to have been uniformly very severe on an intervening crop of tomatoes and peppers.

This test involved tomatoes of the fall crop of 1948. The field was prepared and bedded on Aug. 20 and the fumigants were applied at four to six inches depth with Mack guns on Aug. 21. A light rain fell on the night of Aug. 21-22, and enough rain fell during the ensuing week to keep the soil damp. On Aug. 30 the beds were stirred to a depth of five inches with potato forks to allow drying and aeration of the soil. The beds were again stirred on Sept. 1 and tomato plants of a wilt resistant stock were set later in the day. On Sept. 3 it was found that the plants on plots treated with Larvacide were nearly all dying because of chemical damage. All plants involved in the experiment were then eliminated by a deep hoeing that further aerated the beds. The soil was again stirred to five inch depth with potato forks on Sept. 6. All of this hand tillage of the soil to promote aeration and dissipation of the chemicals was accomplished without destroying the original beds. The second and final setting of tomato plants was made on Sept. 8, i. e., 18 days after application of the fumigants. By Sept. 11 it was obvious that the normal and double dosages of Larvacide were still damaging some plants. However, since it was considered important to have the crop in season with the commercial production of the area, it was decided to proceed with this stand and do no fill-in resetting.

No cultivation that could throw non-treated soil from the middles to the treated beds was done until Sept. 20, and then it was held to a minimum. Otherwise the crop was given standard treatment for staked tomatoes of the area, the fertilization, cultivation, and spraying for control of diseases and insects being as recommended by the laboratory.
The results of this test of soil fumigants are summarized in Table 1. The yield data are totals of seven consecutive weekly pickings, and are not corrected for stand or plant count. The poor yields from the normal and double doses of Larvacide are without question a reflection of the stand reduction caused by the chemical. This is pointed out merely in fairness to a highly effective soil fumigant. However, Larvacide was included in the test only to serve as a check, there being no prospect that it could be recommended for general usage by growers because it is too dangerous and disagreeable to be handled by any except cautious and skilled workmen.

D-D and Soil-fume 80-20 caused no reduction in stand. However, it was noted that the plants on a plot treated with Soil-fume and located at the lower end of the field grew to eight or ten inches height and then made no progress for two weeks while plants on nearby plots treated with D-D and Larvacide were making good growth. The plants on this retarded plot made strong recovery after the delay of two weeks and eventually produced a good yield of high quality fruits. An observant grower of the district reported a similar retardation for the same period on wet land treated with Soil-fume, his field affording the comparison between D-D and Soil-fume. This retardation of growth where the soil holds excessive moisture after treatment with Soil-fume nicely exemplifies the type of important factor or relationship on which our information is insufficient to warrant recommendations to growers. It appears certain that soil type and seasonal rainfall are important variables that will require considerable study before general recommendations can be made. The soil type on which the tests here reported were conducted is Manatee fine sandy loam, heavy phase.

The root-knot severity ratings shown in Table 1 were taken by digging and examining the roots of all plants in the test. This could not be done until Dec. 31, 1948, after the final weekly harvest, of course. The numerical scale used for the ratings were devised for comparison of tomato breeding lines under test for resistance to root-knot. For this reason, the lower the rating the more severe was the root-knot. The scale is as follows:

0—Severe root-knot with galls mostly ruptured.
2—Moderately severe root-knot with approximately half of galls ruptured.
4—Moderate root-knot with few galls ruptured.
6—Slight root-knot with some galls size of pea but none ruptured.
8—Very little root-knot; galls few and small.
10=No root-knot.

As suggested by the data presented, none of the treatments prevented root-knot and practically one hundred percent of the plants showed more or less galling. However, there is good reason to believe that yield is not reduced by root-knot of the classes represented by numerals six and eight, provided the plant had opportunity to become well established before the infections occurred. In other words, it appears that a root-knot severity rating of 6 or higher, referring to the scale and table above, can be taken to mean that yield probably was not influenced by root-knot. It

<table>
<thead>
<tr>
<th>Fumigant</th>
<th>Bu. Marketable Amt. per A.</th>
<th>Tomatoes per Acre</th>
<th>Average Root-Knot Severity Ratings*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larvacide</td>
<td>250 lbs. 282</td>
<td>6.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>125 lbs. 300</td>
<td>6.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>62.5 lbs. 350</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average 311</td>
<td>5.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100 lbs. 339</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50 lbs. 355</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25 lbs. 329</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>D-D</td>
<td>Average 344</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>Soil-fume 80-20</td>
<td>13 gal. 314</td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.6 gal. 313</td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.25 gal. 319</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average 347</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 246</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 245</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Non-Treated</td>
<td>0 254</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td>Controls</td>
<td>Average 248</td>
<td>2.9</td>
<td></td>
</tr>
</tbody>
</table>

* Evolved from an inverse scale ranging from 0 to 10. The higher the rating the less severe was the root-knot.
seems reasonable to assume, of course, that galls represented by six and eight ratings were caused by late-season infections.

The point of prime concern to growers indicated by the yield data shown in Table 1 is that a double dose of the fumigant shows no advantage over the normal or regular dose. This information may enable many growers to reduce their production costs and still reap maximum benefits from the use of soil fumigants. Biometrical analysis of the plot yields on which the summation presented in tabular form is based shows that yield did not vary with dosage, but shows clearly that all three doses of all three chemicals gave great advantage over no treatment. Biometrical analysis further indicated that doubling the dose of fumigant gave no reduction in severity of root-knot over the normal dose, but that cutting the dose to half-rate allowed significantly more severe root-knot without significantly reducing yield.

A third test furnishing tomato yield data on the influence of soil fumigation with ethylene dibromide was carried out in the spring of 1949. This test was made on a field that had been treated full scale with D-D on Aug. 15, 1947. The tomato crop put on it for the fall crop of 1948 had been ruined by root-knot. Hot, dry weather conditions prevailed during almost the entire spring crop season. It is considered, because of the circumstances mentioned in the preceding two statements, that this was a most severe test of soil fumigation for nematode control. The prime objective was to compare in-the-row application with conditions.

The results in terms of marketable (U. S. No. 1 and No. 2) tomatoes show no significant differences between in-the-row fumigation and full-scale fumigation, but they show that Soil-fume 80-20 applied either way roughly doubled the harvest, the average yields being 105.2 bushels per A. for plots not fumigated and 216.2 bushels per A. for plots fumigated in-the-row. The yield from plots treated full-scale was 184 bushels per A., this figure not differing significantly from the 216.2 for in-the-row treatment.

In terms of root-knot control ratings, the results of the spring 1949 test show in-the-row application superior to full scale application, which is in turn superior to mineral spirits (diluent used in reducing concentration of Soil-fume 60-40) and to no treatment in controlling root-knot. There was no suggestion that the best treatment could prevent the development of root-knot under such conditions.

It appears desirable to mention that the writers have not yet observed a case of soil fumigation on a field scale, regardless of method of application, in which the treatment prevented the development of root-knot on a susceptible crop that remained in the field for as long as three months. There seems to be no doubt that the longer the term of the crop the greater the need for perfection in the control of nematodes. Further, it appears only reasonable that the grower must take every possible precaution that will help in attainment of perfect control of root-knot in seed-beds. There is not much point in fumigating a field for control of root-knot if the plants to be set in it are already infested.

The tedious hand procedures necessary for our early studies on in-the-row application of soil fumigants prompted the junior author to design a simple, inexpensive, effective, home-made attachment for the bedding-cultivating tractor that has proven a very useful in-the-row applicator on the experimental farm and is being used as a model by many farmers and some supply agencies of the district. In our use of the rig the application of fumigant, application of original charge of fertilizer, bedding and boarding-off are all done in the one operation. The fumigating attachment, or one just as satisfactory for the purpose could be made by any handy-man farmer for very little expenditure of time; and the cost of the materials need not exceed $5.00. The essential features of the attachment are as follows:

1. A 10 gallon steel drum (an old chemical container) mounted on the front axle of the tractor, the drum having, near the bottom, a galvanized pipe outlet soldered to it;
2. A 5/16" diameter copper tube ex-
tending from the outlet in the drum to proper position to place the trickle of fumigant in a line representing the approximate center of the bed formed by the discs;

3. A shut-off valve near the base of the drum and controllable from the driver's seat; and

4. A regulator valve in the line of copper tubing.

The regulator valve is set for the desired gallonage per acre by trial and error, as follows:

1. The tractor-driver determines the position of all controls when tractor is moving at normal, steady pace in the preparation of beds;

2. By taking the average of several readings, the number of seconds required for the tractor to move 100 feet at the steady working pace is determined;

3. By calculation it is determined how many cubic centimeters of the liquid to be used are required to treat 100 feet of row at the desired dosage;

4. The regulator valve is changed until it allows the proper volume of the fumigant to flow into a graduated container in the number of seconds required for the tractor to move 100 feet. The tractor is standing still for this calibration, of course.

The above-described apparatus allows the adjustment and control of application rate per acre with satisfactory accuracy under our conditions, which include a first-class tractor driver.

As delineated in preceding paragraphs, our experience to date clearly indicates that the proper dose for maximum net gain is 2.5 cc. of Soil-fume 80-20 per foot of row. For D-D the rate is the same. For Dowfume W-40 or Soil-fume 60-40 this becomes 1.25 cc. In terms of full strength ethylene dibromide, this means 0.5 cc. per foot.

Since our rig is dependent upon gravity for the flow of the liquid we believe there is definite advantage, for the sake of uniformity, in arranging for a relatively strong flow instead of a mere trickle. In general practice we now use one measure of Dowfume W-40 or Soil-fume 60-40 diluted with two measures of mineral spirits, and apply approximately 3.75 cc. of this mixture per foot. This means, that, with rows four feet apart, about 10 gallons of the mixture are required to treat an acre.

The cost, at current prices, for materials to treat an acre as described in the preceding paragraph is roughly $9.00. Since our results show a net return of approximately 100 bushels of marketable green-wrap tomatoes for this expenditure, it appears that the grower operating on old sand lands can well afford to take the trouble to fumigate. The writers have used this fumigation procedure in recent crop seasons for peppers, pole beans, and cucumbers with good results but have collected no data on the yield responses shown by these crops.

In the face of the enticing possibilities for the vegetable grower to gain by chemical soil fumigation, as suggested by the foregoing, the writers feel it necessary to reiterate their introductory remark that we still know dangerously little about the subject. Let us, in closing, enumerate some questions on which we do not have enough information.

1. Can soil fumigant be used repeatedly on a valuable tract of land without lasting damage of some type?

2. Will the responses observed on Manatee fine sandy loam (heavy phase) be representative of responses from other soil types used for vegetable production in Florida?

3. Will a fumigant always be harmless in-so-far as quality of all vegetable crops is concerned?

4. How long after fumigation must the grower wait before each crop can be seeded or set? Conceding that soil moisture is an important factor in this connection, how can the grower determine when it is safe to start the crop?

5. Is it advantageous to seal the soil surface after treatment if the chemical is applied while the soil is damp?

6. What is the proper usage of fertilizer in relation to soil fumigant?

The Agricultural Experiment Stations are striving to determine the answers to these questions as soon as possible.