METHODS OF FUMIGATION AND FERTILIZATION BETWEEN SUCCESSIVE CROPS IN ESTABLISHED PLASTIC MULCH COVERED BEDS

NORMAN C. HAYSLIP
Agricultural Research Center,
University of Florida,
P. O. Box 248, Fort Pierce, Florida 33450

J. WAYNE MISHOE
Agricultural Research and Education Center,
University of Florida,
P. O. Drawer A, Belle Glade, Florida 33430

RONALD M. SONODA
Agricultural Research Center,
University of Florida,
P. O. Box 248, Fort Pierce, Florida 33450

Abstract. An IFAS tractor-mounted square-bar applicator was used to apply fumigant and liquid fertilizer in established plastic-mulch covered beds. The beds and mulch remained intact. Inhibition of tomato seed germination and reduction in populations of potential plant pathogens indicated that fumigation was effective. Sweet corn planted as a second crop on plastic-mulched beds previously cropped to tomatoes, displayed positive growth and yield response to liquid N and K₂O applied with the square-bar. An automatic plug-mix planter was modified and successfully used to deposit dry fertilizers into beds through the plastic mulch. There was a 79 percent increase in yield in a second tomato crop where supplementary fertilizer was added via the plug-mix planter to fertilizer left in mulch covered beds from the first tomato crop.

Soil borne diseases and/or nematodes may build up to damaging levels by the end of a first crop in plastic-mulched beds. A means of treating these beds for a second crop is needed. In many cases residual fertilizer will need to be supplemented for maximum second crop yields. Methods of applying fumigants and fertilizers without damaging the plastic should make a second crop more reliable and profitable. If a method of applying fumigants and fertilizers to established plastic-mulch covered beds is developed it is possible that long-lasting plastic mulch can be used for successive cropping for a period of 2 or more years.

A program designed to develop machinery and methods for fumigating and fertilizing established plastic-covered beds has been underway since 1975. The program has resulted in the development of a rotating, hollow, square bar for fumigant and liquid fertilizer application (2). An evaluation of the machine, and the development and testing of a modified plug-mix planter for applying dry fertilizers to mulched beds are reported here.

Fig. 1. Fumigation beneath newly made plastic mulch covered beds for first crop. Note good condition of plastic on fumigated bed in foreground.

Experiment 1. The machine was first tested on newly formed beds with and without plastic mulch with Vorlex as the fumigant. Fertilizer (4-16-4) was applied on the soil surface in 2 bands at 700 pounds per acre and beds formed over the fumigant on December 5, 1975. Beds to be covered with plastic received an additional 1200 pounds of 8-12-20 per acre² in 2" deep grooves on bed shoulders. Treatments applied on December 30 were (1) Vorlex applied at 35 gallons per acre with the square bar—mulched (2) the same without mulch (3) square bar with fumigant turned off with mulch (4) same as (3) without mulch. There were 4 replications of one 65 ft. long single bed for each treatment. Tomatoes were plug-mix (1) seeded 14 and 29 days after fumigation. Six-inch-deep cores of soil were collected from 8 locations per replicate on each seeding date to determine levels of potential pathogens. The soils were assayed for propagules of water molds using Tsao and Ocana's P₁₀VP medium (5). Populations of Fusarium propagules were determined using the medium developed by Nash and Snyder (9). Seedling counts in the first planting were made 10, 13, and 28 days after seeding. Counts in the second planting were made 12, 16, and 19 days after seeding. Plants from the second seeding were thinned and grown to maturity.

Materials and Methods

Fumigation

The IFAS tractor-mounted square bar machine (Fig. 1) was designed to deliver liquids in 1 to 5 bands into the beds with minimal disturbance of the plastic mulch. A ground driven piston pump forces liquids through a manifold into copper tubes which terminate at the exit holes in the hollow bar. The rotating bar moves under the bed, at about the same level as water furrows, and perpendicular to the down-row travel of the tractor. In operation the bar lifts the edges of the buried plastic momentarily. The edges drop back into place as the bar clears. Press wheels compact the soil leaving the plastic tight and secure.
Experiment 2. In the spring of 1978, Vorlex was applied at 35 gallons per acre (315 liters/ha) to newly formed beds with a Kennco plastic laying machine equipped with 5 fumigation knives or chisels, and the square bar machine with 5 orifices. Unfumigated beds served as checks. The Kennco machine was used to fumigate plots and lay plastic on January 31, 1978. The chisels were then removed from the machine and it was used to lay plastic on the rest of the plots. The square bar machine fumigation treatments were made February 1, 1978. There were 5 replications per treatment. Each replicate consisted of a single bed 35 ft. long with 15 ft. buffers down-row between plots. On March 1, 'Carolina' cucumbers were plug-mix seeded using the automatic plug-mix planter. On March 21, cucumber seedling counts were made. The plastic mulch was removed from the beds on April 12 after the cucumber vines began to grow in order to obtain fruit rot data. Eight cores of soil were obtained from each of 3 replicates of each treatment on April 4 (62 days after fumigation) from unplanted areas of the beds. *Pythium* and other water molds were assayed using Tsao and Ocana's medium (5). *S. rolfsii* was assayed using a technique described by Sonoda (4). On May 2 (90 days after treatment) undetached young cucumbers (2 to 4 inches long) were buried in soil in the beds. Two weeks later the fruit were checked for fruit rot incidence.

Experiments (dry application)

An automatic plug-mix planter manufactured by Mechanical Transplanter Company (1) was modified for testing the feasibility of applying dry fertilizers into plastic-mulch-covered beds (Fig. 3). Early tests revealed the weight of the fertilizer resulted in frictional strain on the agitator and metering device. This problem was solved by suspending a second hopper inside the machine's mounted hopper and securing a cone-shaped plate with a 3-inch diameter hole at the base of the suspended hopper (Fig. 3). This allowed fertilizer to feed through by gravity into the mounted hopper as needed, and relieved the weight from the agitator and metering device.

Fertilization (dry application)

The planter was further modified to apply dry fertilizer, water and transplants in one tractor operation as shown in (Fig. 3). Two seats and two plant tray holders were mounted on the axle of the planter, and the automatic watering device was activated. Three plug-mix planter pockets were alternated with 3 transplant pockets on the main control disc. Plug-mix pockets tripped the fertilizer metering unit and received a measured amount of fertilizer. The transplant pockets served to punch holes in the beds for planting of transplants. With these modifications, fertilizer was deposited 2 to 3 inches deep at 20" intervals. The transplant holes were formed midway between holes with fertilizer plugs. Water was deposited in fertilizer and transplant holes. Workers seated on the planter placed container-grown plants in the transplant holes while the holes were still full of water. The transplant method is similar to the very efficient water wheel plant setter manufactured by Kennco Manufacturing Company, Ruskin, Florida.

Experiment 4. The initial test with dry fertilizer was established in the fall of 1977. Paraquat was used to kill old tomato plants and weeds on plastic mulch covered beds. Tomato plants were removed before the beds were fumigated with 35 gallons Vorlex per acre on July 20, 1977 using the IFAS square-bar applicator. This tomato test on 4-mil plastic mulch beds had three treatments: (1) tall stakes (2) short stakes and (3) no stakes. On one-half of each plot the plants were pruned. Two replicates received fertilizer and two received none. The plot design was such that 10 direct comparisons of fertilizer vs no fertilizer were possible. Walter tomatoes were transplanted August 24, 1977, 24" apart in the center of the beds. A plug-mix pocket from the automatic plug-mix planter was used to apply 500 pounds per acre of 17-0-34 September 12. The fertilizer

Fig. 2. Inhibition of tomato seed germination as indicator of Vorlex distribution and retention. Right bed—left row seeded 14 and right row 29 days after fumigation. Left bed—in non-fumigated check excellent germination and growth both seeding dates.

Fig. 3. Automatic plug-mix planter modified for applying dry fertiliser, watering and transplanting second tomato crop in one tractor operation.

was a mixture of ammonium nitrate and potassium nitrate. The fertilizer was placed mid-way between tomato plants about 3" deep. In plots which were staked, the stakes were driven in the holes containing fertilizer. All fruit at the breaker stage, or riper, were harvested November 10, 22, 29, December 5, 14, and 20.

**Experiment 5.** A third successive crop consisting of tomatoes and cucumbers was planted in 4-mil plastic-mulch covered beds in the spring of 1978. Bacterial wilt resistant tomato Hawaii 7997, which produces small fruit but sets well during hot weather, was planted in the two blocks which had received no supplementary fertilizer during the fall of 1977. ‘Carolina’ pickling cucumbers were planted in the two blocks that had received 500 pounds of 17-0-34 of N and 32 pounds of K per acre. The machine operated satisfactorily at a speed of 1 mile per hour. Modifications on the automatic plug-mix planter for applying fertilizers were simple and inexpensive.

### Results

**Fumigation**

In experiment 1, levels of Vorlex that inhibited tomato seed germination and seedling growth remained in mulched and unmulched beds 14 days after treatment (Fig. 2 and Table 1). Tomatoes seeded in plastic-mulched plots 29 days after fumigation were not significantly different from those in non-fumigated plots, and resulted in a standard deviation equal to the non-fumigated check. However, in non-mulched plots the rate and number of seedlings emerging in fumigated plots were less than in unfumigated check plots, indicating Vorlex had not dissipated enough after 29 days. No water molds were detected in mulched or unmulched fumigated beds 14 or 30 days after fumigation (Table 2). The population of water molds was nearly the same for both assays. The population of Fusarium propagules was much lower in fumigated beds than in unfumigated beds 14 days after treatment.

In the spring 1978 trial (Experiment 2), cucumber seed germination and seedling survival were best in the non-fumigated check and poorest in the square-bar treatment, with the Kennco chisel treatment having an intermediate effect. Since no disease-inciting organisms were detected in damaged seedlings the fumigant was probably responsible for these differences. Neither water molds nor S. rolfsii were detected in Vorlex-treated plots (Table 3). Only a few fruit rotted, and all were in unfumigated plots.

**Fertilization**

**Liquid fertilizer.** In experiment 3, sweet corn plants were larger and had a richer green color where the liquid fertilizer was applied (Fig. 4). Near harvest these fertilized plots displayed some N deficiency, indicating the need for a higher rate of fertilizer for maximum yields. However, a yield increase of 126% was obtained from the 57 lbs. of N and 32 pounds of K2O applied per acre.

**Dry fertilizer.** Modifications on the automatic plug-mix planter for applying fertilizers were simple and inexpensive. The machine operated satisfactorily at a speed of 1 mile per hour.

---

Table 1. Effect of fumigation on tomato seed germination (Experiment 1).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1976 date</th>
<th>Average number of seedlings/25 hills</th>
<th>Number hills with one or more seedlings/25 hills</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vorlex</td>
<td>January 23</td>
<td>0</td>
<td>44a</td>
</tr>
<tr>
<td>Check</td>
<td>January 23</td>
<td>60</td>
<td>20</td>
</tr>
<tr>
<td>Vorlex</td>
<td>January 26</td>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>Check</td>
<td>January 26</td>
<td>111</td>
<td>24</td>
</tr>
<tr>
<td>Vorlex</td>
<td>February 9</td>
<td>85</td>
<td>39</td>
</tr>
<tr>
<td>Check</td>
<td>February 9</td>
<td>117</td>
<td>24</td>
</tr>
</tbody>
</table>

Table 2. Levels of Pythium and Fusarium in soil of mulched and unmulched beds following fumigation (Experiment 1).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mulch</th>
<th>Days after fumigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vorlex—35 gal./acre</td>
<td>yes</td>
<td>0a</td>
</tr>
<tr>
<td>Check</td>
<td>yes</td>
<td>10a</td>
</tr>
<tr>
<td>Vorlex—35 gal./acre</td>
<td>no</td>
<td>0a</td>
</tr>
<tr>
<td>Check</td>
<td>no</td>
<td>49b</td>
</tr>
</tbody>
</table>

Table 3. Effect of rotating bar and standard chisel fumigation with Vorlex on population of water molds, population of Sclerotium rolfsii and incidence of cucumber fruit rot (Experiment 2).

<table>
<thead>
<tr>
<th>Fumigation method</th>
<th>Water molds</th>
<th>S. rolfsii</th>
<th>Incidence of fruit rot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard chisel</td>
<td>0a</td>
<td>0a</td>
<td>0a</td>
</tr>
<tr>
<td>Square-bar</td>
<td>0a</td>
<td>0a</td>
<td>0a</td>
</tr>
<tr>
<td>Not fumigated</td>
<td>10b</td>
<td>0.16b</td>
<td>1.0b</td>
</tr>
</tbody>
</table>

**Fumigated on February 1, soil assayed on April 4, 1978. Numbers followed by the same letter are not significantly different at 5% level.**

---

per hour. Because of the caustic effect of the fertilizer salts it was necessary to thoroughly wash the machine after use, and to apply oil to all moving parts exposed to the fertilizer.

Second-crop tomato plants in experiment 4 receiving 500 pounds of 17-0-34 per acre plugged in bed center at 24" intervals were larger and had better foliage color than plants in unfertilized plots. The fertilized plots yielded 79% more tomatoes (32.7 tons) than unfertilized plots (18.3 tons per acre). Size of early fruit was larger in the fertilized plots. In experiment 5 tomatoes and cucumbers grown on plastic mulch covered beds as a third successive crop produced well. Although 15% more tomatoes and 10 percent more cucumbers were harvested from plots plug-fertilized on both sides of the row compared to plots fertilized on one side, the differences were not significant (Table 4).

**Discussion**

The IFAS square-bar applicator provides vegetable growers with a mechanized method of delivering fumigants and liquid fertilizers into established plastic-mulch-covered beds. Since supplementary fertilizer requirements may be high, up to 200 gallons of liquid per acre may be needed. Therefore, it may be desirable to have inter-changeable square-bar and liquid delivery systems, one for fumigants and the other for fertilizers. The square-bar machine cannot be used where stumps or other large obstructions exist. However, a safety disconnect system might be incorporated if the machine comes into general use.

The modified plug-mix planter was successfully used as a method of supplying high analyses dry fertilizers for successive cropping on mulch-covered beds. Since the planter is commercially available and easily modified to apply fertilizer in plugs 10" or more apart, this system is available to growers now. For those growers who want to fertilize and transplant 20" or 30" apart in one operation the additional modifications described in the text and shown in Figure 3 can be incorporated with little additional cost. Thoroughly washing the planter to remove caustic fertilizers and oiling all moving parts after use are necessary to keep the machine in good condition.

Since machines and concepts are new, growers should first use them on a few acres after obtaining more detailed instructions from the authors or their County Extension Directors. In some cases the IFAS machines can be taken to growers for testing on their farms.

**Literature Cited**